FARM PRODUCTS IN INDUSTRY

Photograph courtesy of Cornstalk Products Company

THE SIGN OF A NEW INDUSTRY

Part of the 10,000 tons of cornstalks gathered by the Cornstalk Products Company for their factory at Tilton, Ill., in 1927-28 to be manufactured into cellulose pulp. With an average truck-haul of 15 miles, the average cost of baled cornstalks was less than $8 per ton delivered at the factory. A considerable quantity cost less than $6 a ton.

FARM PRODUCTS IN INDUSTRY

By

GEORGE M. ROMMEL

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To

S. R. R.

PREFACE

This book is based on a survey which the author made during the winter of 1927-28 for Hon. W. M. Jardine, United States Secretary of Agriculture, of research data in Washington and elsewhere which have a bearing on the industrial utilization of farm products. The plan under which the survey was conducted outlined:

1. A survey of—
   a. The present utlization of farm products in industrial processes.
   b. The possible extension of industrial uses of products which already have a partial market for industrial purposes.
   c. The possible development of the industrial outlet for farm products now used mostly or entirely for food or feed.

2. To compile the important research data thus far obtained by various Government agencies on the problem, and, as far as practicable, of that done by other institutions in the United States.

3. To indicate the organization and direction of coordinated research work which will point the way to further practical extensions of the consumption of farm products in the industrial field.

The author wishes to express formally his appreciation and thanks to Secretary Jardine for making this

survey possible and for his permission for prompt publication of the information contained in it. It is also fitting in this place to thank Dr. A. F. Woods, Director of Scientific Work of the United States Department of Agriculture, for his whole-hearted support and coöperation.

GEO. M. ROMMEL.

Pleasantville, New York,
May 29, 1928.

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CHAPTER I

INTRODUCTION

The Farmer feeds the World!

True beyond a doubt as this maxim is, the fact which it exemplifies has been ascribed as at least a partial reason for the rigidity of the farmer's economic position. The supply of food depends for its consumption on the somewhat inelastic demands of the human stomach. The world has not gotten over its fear of starvation, and the idea still prevails that it is always possible to eat just a little more of this or that. The advertising experts are learning better, however, and "eat more" campaigns are gradually fading out. If we eat more of one food we eat less of another; the prosperity which may come to the producers of one foodstuff on account of an increase in its consumption may be attended at the same time with a depressed condition among farmers producing one which we may have displaced under the temptation dangled before our eyes by aggressive competitive salesmanship.

Furthermore, it has been repeatedly observed that the tendency among people as their knowledge of physiology increases is not to eat more of anything, but to eat less of everything. This may be hard on the producers of food, but it is a fact which they must face if they are not to be frequently caught in a jam of overproduction. Any one who was in France during

the War, soldier or civilian, can testify to the small amount of food on which a person can subsist if it is absolutely necessary. The rule of the animal husbandman can be applied to the nutrition of the human race —feed the young things to repletion; go easy with the adults. It is almost impossible to give a youngster too much to eat, if he has sufficient exercise, as all mothers can testify. Any man who stops to think knows perfectly well that most of his troubles after he reaches the age of thirty come from the food he eats—not the kind, but the quantity.

For two weeks on one occasion it was my misfortune to be obsessed with the idea that economy could be efficiently practiced by preparing my own meals; it happened that I was entirely alone, and there was not the least domestic obstacle to the inauguration of the experiment. In carrying it out, no trouble followed the culinary efforts; they were quite satisfactory in every respect. The difficulty was in adjusting buying to the requirements of my one-individual consuming market. I found that unless I was very careful, I would buy more than I needed, and waste would result from spoilage. I have a horror of waste. Inviting friends to share in the consumption helped somewhat, but it was not the proper approach to the solution of the problem. The difficulty could be met only by a continual effort to buy just as much as was needed at the time and no more; and so my purchases kept growing less and less. It was real "hand-to-mouth buying." I then learned to have a lively sympathy for food merchants, but it did them no good to blandish me with hails and smiles and

other adjurations. I was adamant. Only on canned goods did I permit myself to stock the pantry shelves against future contingencies and even there I was cautious. At least twice each day (after meals) I was out of the market for food.

On things inedible I was under no such restrictions of conscience. I was always in the market for those things. Anything up to an automobile or a piano would tempt me to spend hours of my own and a salesman's time. Of course, it is hardly necessary to say that no new car filled the garage with its magnificence when the family returned, nor was there a new piano in the living-room; but neither the salesmen nor I had expected either of those eventualities to transpire. So there was no misunderstanding.

My budget permitted buying all the food I needed and more. The difficulty with the piano and auto propositions was the lack of adequate purchasing power. Consistent, systematic saving, continued for a sufficient length of time, would have made it possible for me to add these or other expensive products of industry to my inventory. I had the money to buy much more food than I needed, but did not spend it all for food. If I had had the money to buy inedible things like pianos and automobiles I should undoubtedly have done so. As it was, I spent much time in one of Mr. Woolworth's well-known Emporiums, where I had the satisfaction of knowing that I had sufficient funds to buy anything I saw and liked!

It is a human trait to spend money when one has it in abundance beyond the needs for food. This fact is

a fundamental principle of salesmanship and many industrialists believe that the prosperity of America to-day comes from its widespread application. The idea is scouted by a large school of competent economists and it seems to be diametrically opposed to the well-known New England principles of economy. It is a fact, however, that American people have an ingrained habit of spending their money when and if they have it, and the only person in the United States who practices rigid economy while he is in the possession of abundant means to gratify every whim, is our distinguished and dignified Uncle Sam.

As long as the approach to Uncle Sam is somewhat difficult for a salesman to negotiate with satisfaction to himself, the average business man with something to sell concentrates his attention on the pocketbook of his fellow man, knowing that the other fellow is equally keen on reciprocating to the best of his ability. The result is a rapid circulation of money which "makes business good." Time will tell whether it is also good for business.

Now how far can this revolutionary principle in practical economics be brought to have an influence on farming? Within the limits of his means, the farmer is an active purchaser of the products of industry. For example, he has an automobile, and must needs buy gas and oil, tires and parts. A radio receiving set is an essential part of modern farm equipment, and the farmer's family goes regularly to the movies.

When the farmer's business is food production, he exchanges for these things by money, the medium of

exchange, food products for which the demand is inelastic, as we have seen. This tends to make an uneven balance in the exchange. The farmer should not be begrudged the enjoyment of the good things of life, but the fact that he has not been able to obtain certain advantages as readily as the man in town is at the bottom of his dissatisfaction with his job.

Shall the farmer, therefore, become a producer of industrial raw materials? Shall we advise farmers to eliminate food consumption from their activities and concentrate on the production of something which will go into manufacturing channels and become in time industrial products for which the demand may be more elastic than the demand for food? That would be the logical outcome of these arguments, but the fallacy in them appears at once. If farmers should do this, shortage of food would immediately result, there would be a surplus of materials for manufacture, farmers who were producing food would make money beyond their wildest dreams, food would replace oil and utilities as subjects for congressional and administrative investigations and the food-producing farmers would become the target for all kinds of animosity while those who were producing for the industrial outlet would go broke.

The sounder viewpoint is to approach this question as the meat packer did when he found that he could reduce his losses, add to his income, pay his overhead and enhance his chances of making money, by using everything which came to his hand, as far as he found that he could thereby make a profit.

The elimination of waste, the utilization of by-products which are the inevitable accompaniment of most major operations in production, is the correct aim to be pursued, rather than a change in the plan of production. Addressing a conference in Washington some two years ago, the Honorable Secretary of Commerce, Mr. Herbert Hoover, said: "The elimination of waste is all assets—it has no liabilities." With a qualification which was doubtless in the Secretary's mind, that it must not cost more to eliminate waste than to allow it to continue as waste, this statement is quite as true in farming as it is in industry.

To this fact may be largely ascribed the greater success of the livestock farmer compared with that of the farmer who depends on only one single outlet for his productive activity, such as wheat alone or cotton alone. He may be a producer of market milk or hogs or steers as a specialty, but he is also a producer of hay and grain, marketing them through his livestock. In any case, he has at least two strings to his bow and a slump in the price of his main product does not necessarily mean that he will be seriously handicapped. If he charges the feed which he produces on his farm at market prices, he will actually be the gainer even when his milk or animals are sold at no more than bare cost of production; and if cost of production includes interest, depreciation and overhead and his own labor as well as that of members of his family, as it should do, he is going ahead all the time by reason of the profits which he makes on home-grown feed and the satisfactory compensation for the labor used.

The successful diversified farm seldom has the appearance of a "variety store," holding all kinds of goods on its shelves in the hope that a customer may some day want some particular article. The diversified farm should be diversified in its production; it need not be diversified in its market. A dairy farm, for example, with but one market for its main money crop, may be in a strong and sound economic position if the major part of its feed requirements are produced on the farm and the entire time of the operator and his staff is taken up with the care of the herd and its maintenance, with as little time as possible spent in producing things which may be purchased more economically than they may be produced. "The delights of country living"—fresh fruit, vegetables, home-produced bacon and hams, eggs, poultry and so on,—may be quite expensive luxuries on a working farm run as a business to make money.

As a further elaboration of this thought, attention should be directed to the fact that as a general rule the single-crop grain or cotton farmer incurs a year's outlay of expense for land rent, seed, fertilizer, machinery, feed, horse and mule labor, hired man labor and his own time in the production of a crop less than half of which he can utilize completely or find a market for, directly or indirectly.

For every pound of shelled corn grown, about 1½ pounds of corn stover (stalk, leaves, husks and tassel) are produced. For every pound of wheat harvested and threshed, there may be as much as two pounds or more of straw. Similar proportions of straw are produced by other cereals and we would doubtless find a large waste

in potato tops if we should weigh them up. East of Pittsburgh the by-products of grain production are quite completely utilized, but as we go further west less and less use is made of them.

In growing a crop of cotton, it would appear that the weight of stalks, leaves, and burs produced is two or three times as great as that of the "seed cotton" produced (seed cotton is cotton before the lint and seed are separated in the cotton gin). All except the seed cotton becomes waste as soon as the crop is harvested, utilized only as winter cattle pasture and for the fertility value which may be reclaimed from the cotton stalks. If lint cotton and cotton seed were not such highly valuable products, the waste in the rest of the cotton plant would bankrupt the cotton grower.

Fruit and vegetable growers do not work under so great a handicap. The wastes on such farms are relatively unimportant. The fruit grower produces only his apples, or peaches, or pears, oranges, lemons or grapefruit; no great weight in leaves goes with them; no straw or stalks have to be disposed of. The twigs, branches and limbs burned after the annual pruning are the only waste products of fruit growing which are at all analogous to the inevitable waste which accompanies grain production, and larger, finer crops of fruit more than compensate the grower for the cost of pruning. The fruit grower's waste comes from his culls, for which a market is usually found. The truck farmer sells his vegetables, tops and all, or has a waste left behind which does not represent a large proportion of the total weight produced by the crops.

The question of the fertility removed from the soil in these waste products will immediately arise in the reader's mind. This subject is discussed at length in a later chapter. It may be remarked here that there is some danger of overemphasizing this point.

A farmer's soil is like his bank account. He can draw out no more than his original deposit and what he subsequently puts in. After the virgin fertility of the soil is exhausted, plant food must be constantly added, and the farm operator finally comes to realize the truth of the statement attributed to a German chemist: "A good soil is a good place to put fertilizers." The physical condition of the soil then becomes much more important than its chemical content, because the amount of plant food can always be increased by the application of fertilizers to the soil, whereas much more expensive treatment may be required to correct a defective physical condition.

The farmer who is building and not robbing his soil will be careful to see that his fertility balance is always on the credit side, and steadily increasing to the full limit of productivity. To such a man, the amount of fertility which he sells from the farm is not important, although he should know how much it is. The important thing for him to be dead sure about is that the fertility removed is more than counterbalanced by fertility added to the soil by legumes, by stable manure and by commercial fertilizers.

If a farmer can sell the waste products of grain production for enough to enable him to buy sufficient commercial fertilizers to replace the fertility sold, and if

he buys and applies them, his account with the soil is evenly balanced. If the price he gets for these wastes is more than their fertilizing constituents are worth, he is better off than if he returned them to the soil. A single legume crop, cut for hay or pastured, and then plowed under, is worth half a dozen crops of straw or cornstalks.

An indirect benefit often follows the complete removal of crop wastes. Destructive plant diseases and insect pests are frequently carried over from one season to another by vegetative material from a preceding crop. In such cases, which are becoming increasingly common in America, it is much better to dispose of these crop by-products in some other manner than by plowing them under, because the risks from disease or insects may far outweigh the value of the fertility which may be conserved.

The wastes which are found on nearly every American farm, especially in the Mississippi Valley, are not now wastes in the economic sense. Up to the present time, their utilization complete would be a greater waste than their destruction by fire; it would cost more to use them than to waste them. If all the straw and cornstalks which accumulate each year on Corn Belt farms were turned into meat and milk, the country could not consume the increased output of food. That fact gives force and point to the agitation which has come about since the War for the utilization of these products in manufacturing.

The new subject bristles with possibilities. Its development rests on chemical research. The chemists,

Photograph courtesy of U. S. Dept. of Agriculture

FILLING THE SILO

A laborious and expensive, but otherwise highly satisfactory, method of utilizing the corn crop. However, less than 5 per cent of the crop is disposed of in this manner.

Photograph Underwood and Underwood

A HUSKER-SHREDDER IN OPERATION

After corn has cured thoroughly in the shock, it may be husked and shredded whenever weather permits it being hauled out of the fields. The husker-shredder may be seen in the center of this picture behind the wagon.

who are responsible for "The New Competition," recognize neither the limitations of their own craft nor the conservative rules of old established methods of production. When the chemist finds that he can make cellulose pulp, paper and other things out of farm wastes cheaper or of better quality than similar materials can be manufactured out of wood, the manufacturer of wood products is forced to meet the new price and quality. No quarter is given in the battle of the chemical industries.

An analogy may be drawn between the manufacture of farm waste and the production of wood pulp similar to that which we noted between the one-crop farmer and the livestock farmer. The producer of wood pulp has but one product and the waste in the manufacture of chemical pulp is at least half of the raw material purchased. The chemists who are working with farm crop wastes claim that an extremely wide range of by-products is possible in the course of manufacture. Prof. Sweeney of the Iowa State College at Ames has shown that some two hundred different products may be derived from cornstalks. Mr. G. H. Harrison, the pioneer in the development of straw for chemical manufacture, claims to find almost as wide a diversity of products in his operations as are obtained in the chemical manufacture of coal tar. Up to the present time the greatest attention in the utilization of crop by-products has been directed towards the things which stand out most clearly on the horizon—the production of wall board and cellulose pulp. It may be that the skill of the chemist in recovering and processing by-products will in time have an effect on these new manu-

facturing industries equal in importance to the rôle played by by-products utilization in the meat-packing industry.

If we carry the analogy a step further back, the importance of this source of competition with timber products becomes still more apparent. The manufacturer of wood products gets his raw material from the main money crop of the forest—wood. The manufacturer of farm wastes gets his raw material from products which are already a by-product of main-crop production. It is a fact that the branches of the timber industry which are most profitable to-day are those which are using manufacturing processes of some kind in their operations and that of these men the most successful are the ones who are making the most complete use of by-products. The value of the by-products of timber production and wood manufacturing operations, such as timber wastes and mill wastes, can only be conjectured at this time because there is neither sufficient nor satisfactory information as to the quantity available or the cost of collecting these raw materials. It should be stated, however, that similar products can be derived from timber waste, wood waste, cornstalks and straw. The competition between these two great sources of raw cellulosic material, therefore, promises to be a lively struggle and one well worth watching by all Americans interested in the industrial development of their country.

So far as the utilization of farm by-products is concerned, the impression should not be allowed to arise that the farmer should sell his waste products for noth-

ing. Neither should the farmer expect to receive a price for his raw material which will make it impossible for the manufacturer to derive a fair profit. This new development cannot succeed unless each party concerned makes money. As the farmer is the first party to the transaction—the producer of the raw material—he should find the utilization of his by-products for manufacture to be a more profitable method of disposing of them than some other method of utilization. Otherwise the first link in this new economic chain will break at the first pull.

The subject involves a broad consideration of farming problems, and of the problems of industrial production as they may affect the farm. There must be a careful consideration of economic, chemical and technical problems. New industrial uses of farm products will have their inception in the chemical laboratory, and the processes evolved in the laboratory must be proved out under factory conditions before extensive use can be made of them in manufacturing. Not only the chemical problem but the engineering problem must be solved. If the chemical process is sound, and practical engineering methods are developed for production, management must then show whether there is a market for the product and whether it can be manufactured and sold at a profit.

Minutes and hours of labor per ton of raw material used, cents per pound of product in chemical processing, must be kept at a minimum because the products used are of low value until they have been manufactured. It is obvious that processes which call for the use of

the largest tonnage of raw material deserve most careful attention if these new outlets for the by-products of farming are to hold much promise as additional sources of farm income. The amount of the material available is enormous, and its use in manufacturing must become general before there is an effect on the welfare of farming as a whole.

The profitable utilization of farm products in industry therefore depends on the solution of the chemical, engineering and management problems involved—management including not only manufacture, but the development of markets as well.

To avoid any possible misunderstanding, it should be pointed out again that this book concerns itself entirely with the production of raw materials and their manufacture into products which are not in the category of food. A consideration of the development of edible by-products, or of new foods from products not now used for food would be large enough in itself to require the writing of a complete book. The meat-packing industry is discussed because it was the first large development in industry based on agricultural products in which complete by-products utilization was attempted; this sufficiently explains the reasons for including some mention of it. With this exception, the author confines himself to consideration of the utilization of products not used for food, and the processes pertaining to their manufacture.

Industry cannot compete with food demands for its raw materials. The soap maker cannot pay the price for vegetable oils and keep on making money out of

soap which the manufacturer of lard substitutes or cooking oil can pay. Skim milk for which there is a market as dried milk for the baking industry will not be made into casein for glue or paper sizing. Even the demand for animal feed will shut a farm product out of the market for raw manufacturing material, and it is a cardinal principle in paper making that the raw material must be something that cannot be economically fed to animals.

CHAPTER II

THE LIVESTOCK INDUSTRY

THE original packing-town wheeze was "The packer saves all but the squeal." The American meat-packing industry is indeed our great classic illustration of a business which has been built up and maintained by the utilization of the by-products of its main operation. The packer turns dozens of things that once were wastes into hundreds of things that now are salable.

Hides and wool, lard and soap stock, were made use of far back in meat-production history. In fact it would take an expert antiquarian to tell us with any reasonable degree of accuracy when it was that men first began to drape themselves with animal skins and weave wool into cloth. The use of animal fats for illuminating purposes and for oiling this and that is probably almost as ancient a custom, but the manufacture of soap is a comparatively modern industry.

Most articles which are derived directly or indirectly from the offal of meat production have had a quite recent origin.

In these days, from the hides and what grows on them, the packer not only gets leather and wool, but brushes, upholstery and plastering hair, felt, glue and lanolin. Blood meal, meat meal, feeding tankage, fertilizers, oils for certain illuminating and lubricating pur-

poses, gelatine, oleomargarine, sausage casings, tennis strings, violin strings, drum heads, surgical ligatures and pharmaceutical preparations come from the insides of animals, while a perfectly amazing array of things, from cigarette holders to nursing rings for the baby are made from bones. It is not the function of the present author to enumerate these matters in detail. The reader who is interested will find the latest and most complete information on the subject in Dr. Rudolf A. Clemen's new book, "By-Products in the Packing Industry," published by the University of Chicago Press.

It is a strong statement, but a true one, that by-products utilization is the life of the modern packing business. This was not always the case. Not so many years ago, the packer was doing a good job when he made lard, salted his hides away carefully and sold sundry and various things to the fertilizer and oleomargarine manufacturers. Meat making was his main business and meat his chief sales product. It still is, but now the packer often gets less for his meat than he paid for the steer on foot.

The entrance of the chemist into the packing industry is responsible for this transformation. Mr. Thomas E. Wilson says that the chemists "started in with refrigeration, with the curing process, with control of the canning, and have made it possible for this business to become one of the largest industries in the world."

Forty years covers the actual working history of chemistry in meat packing, and to H. B. Schmidt, who

in 1886 signed up with a Chicago packer, is given the honor of being the first full-time chemist in the business. It is not an exaggeration to say that, without the utilization of the by-products, the modern meat-packing industry could not exist, which is equivalent to saying that chemistry is vital to the meat-packer.

The ultimate efficiency of this phase of the packing industry has not been reached. New uses are constantly being found—new wealth created. Materials that were formerly used entirely as sources of soap stock and fertilizers now furnish large quantities of valuable animal feed, or even food for human beings.

The development of the pharmaceutical branch of the packing industry has an important bearing on human medicine, and packing-house by-products are the source of some of the most valuable substances known to medical science.

This pharmaceutical material often comes from glands which are so small that only establishments handling large quantities of animals can afford to recover them. For example, the number of posterior pituitary glands in a pound of fresh material is 148, but when this material is processed and ready for the physician to use, 10,360 glands have been required to make a pound of product. The suprarenal gland, from which epinephrin is derived, a substance which constricts blood vessels and makes it possible for eye surgeons to work on the most delicate tissues without hemorrhage, numbers 40 to the pound of fresh material. In a pound of epinephrin which the surgeons use, 25,200 suprarenal glands are represented.

Insulin for the treatment of diabetes was first and is still largely derived from a packing-house by-product, and the development of concentrated liver extract now furnishes physicians with a corrective agent for relief from pernicious anemia which promises to be one of the most remarkable products ever found in a packing-house. Digestive ferments are derived from products of animal slaughter which small butchers frequently throw away because they are too small to warrant the expense of collecting them. Among these are pepsin from stomach linings, rennin from the fourth stomach of calves, and diastase, lipase and trypsin from the pancreas.

The outlet for by-products has much to do with what a packer must get for his main product—meat. Figures from Swift and Company show that from 1915 to 1920 the amount received for beef was less than that paid for the steer on foot. From 1921 to 1924, by-products prices were not so satisfactory and the price received for beef was slightly more than that paid for live cattle. In 1927, the amount received for meat was 83 cents per head less than was paid for live cattle, as we see from the following figures which are taken from Swift and Company's Yearbook for 1928:

Received for meat	$78.10	
Net returns from by-products	14.78	
Total received	$92.88	
Paid for live steer		$78.93
Expenses, including freight		13.00
Profit, before paying interest		.95
	$92.88	$92.88

The by-products from cattle and sheep are more valuable than those from hogs. According to Dr. Clemen, the returns are as follows:

	Percentage from Meat	*Percentage from By-Products*	*Percentage from Hide or Pelt*
Hog	96.6	3.4	Sold with carcass
Sheep	81.4	4.1	14.5
Calf	92.8	7.2	Sold with carcass
Steer	87.3	4.1	8.6

Of course, no one should imagine that the by-products industry is the big end of the packing business. It is not; the packer's main job is manufacturing meat from live animals and selling it. The economic importance of the by-products is that they keep the treasurer's office running smoothly and enable the packer, as shown by the evidence of dollars and cents, to practice that efficiency for which he is famous. The by-products end of the business is to the packing industry somewhat like what oil is to an automobile engine; it is not the source of power, but the machine won't run far without it.

With all this efficiency, however, the packer has not finished his story. Only about 1 per cent of what the packer receives for meat and other cattle products comes from the sale of inedible by-products other than hides, but there is still plenty of room for packing-house chemists and technologists to work in, as the following table from Dr. Clemen's book clearly shows.

Assuming that utilization of the various items in the second column of the foregoing table—hides, fats, head, feet, blood and casings—has been carried to the

maximum of efficiency, there are still three items, "valueless materials," "shrinkage" and "additional shrinkage through processing," which comprise 28.5 per cent of the weight of the steer as bought.

WEIGHTS OF VARIOUS STEER BY-PRODUCTS

	Percentage of green product	*Percentage of finished product to live steer*
Beef	55.6	54.3
By-products:		
Hide	7.2	5.9
Fats	5.0	3.3
Head	3.4	2.2
Feet	1.5	1.1
Blood	3.8	.7
Casings	1.2	.8
Miscellaneous	5.4	...
Valueless materials	10.1	10.1
Shrinkage	6.8	6.8
Additional shrinkage through processing	...	11.6
Total steer	100.0	100.0

According to figures from Swift and Company, the shrinkage which occurs with hogs is somewhat less than in the case of cattle. That company shows that the shrinkage in slaughtering hogs is 20.5 per cent, which, in the case of a 250-pound hog, amounts to 51.25 pounds.

These losses represent weight which the packer has bought and paid for, and which he must charge in with his costs. It is evident that much more than the squeal still gets away from the packer.

The presence in considerable quantities of waste material has thus far defied the skill of the chemist and the technologist. The principal reasons for these losses

are evaporation, loss of blood and the natural difficulty of making a 100 per cent recovery of everything in the work of processing. Here is the opportunity for the chemist and the inventor who work with the packing industry. How much of these "valueless materials" can be made valuable? How much of the shrinkage can be prevented by new machinery or new processes? How much increase in fat recovery can be effected by improved machinery or methods of extraction? How much can the machines and methods already in use be operated with greater efficiency, resulting in greater value in the products recovered?

Hides and Skins:

Hides comprise a larger percentage of the weight of a steer than any other valuable by-product recovered. Dr. Clemen is authority for the statement that only three-quarters of the supply of cattle hides used in the United States come from domestic sources, and of these domestic hides two-thirds are "packer hides" which are taken off the animals at abattoirs having Federal inspection, the remainder coming from farms and small local slaughter houses. The "country hides" are not of such good quality as packer hides, on account of the fact that less care is given them in skinning and curing. It is estimated that losses amounting to nearly or quite $100,000,000 a year are to be charged against country hides and other hides in this country, when to the inferior quality of country hides are added the losses occasioned by grub holes, tick damage and damage from unnecessarily severe branding of cattle.

We import into the United States more sheep, lamb, goat and kid skins than we do of all other kinds of hides combined. The number of goat and kid skins imported runs from 40 to 50 million a year and sometimes more, of sheep and lamb skins about 25 million a year, and of cattle hides and calf skins about 10 million, less than half of which are full-sized cattle hides.

Cattle cannot be raised profitably in the United States for their hides alone, and the relatively low value of the hide, compared with the value of the live animal for meat, is responsible for much neglect of hides. The immense growth of the automobile industry gave leather substitutes their big market, and the automobile manufacturers assure us that if they had tried to upholster with leather all the automobiles which have been made in America since the War there would not have been cattle enough in the entire country to supply the hides which would have been needed!

Be that as it may, the leather substitute story is not done telling. The leather chemist has worked wonders in cutting down the time required to tan a hide into leather, but the chemist who is trying to put leather out of business is constantly on his trail.

Will leather go the way of the beaver hat? It is certainly to be hoped not. Chemists who are not affiliated with the packing or leather industries are singing the swan song of leather, and are insisting that a product made out of cellulose pulp into which rubber latex has been injected looks like leather, outwears leather, and costs less than leather. Something ought to be done about it. It hardly seems reasonable to ask

the animal husbandmen to meet the challenge of the chemists by attempting to breed the hides off cattle; so we must ask the chemists to work out quicker and cheaper methods of making leather, to show us new uses to which leather may be put, or even to devise ways of using cattle skins profitably without making them into leather at all. That remark may make a leather man see red, but it will not disconcert a chemist, because chemists claim to be able to do anything if they have some raw materials to work with, and they recognize no limitations to their craft. Did not the Little Laboratory make a silk purse out of sows' ears garnered from the hog-killing floor of Wilson and Company? They did, and the documentary and visible proof, with every step of the process from the pig's head to the finished purse, may be seen in the museum of Arthur D. Little, Inc., 30 Charles River Road, Cambridge, Massachusetts.

So, really, these omnipotent chemists should not let leather go the way of the beaver hat. Good leather is a lovely thing.

Animal Fats and Oils:

The utilization of fats by the packer is one of the most important branches of the by-products business and perhaps quite the most intricate. Including soap, Dr. Clemen devotes three of the fifteen chapters of his book to this subject.

Lard, most extensively used as food, as you know, is the most important of all fats recovered, but, as it is a food product, we will pass it by.

In early colonial days, the "tallow dip" was the standard lighting equipment in most American homes, and fat from both ruminants and swine had wide use as lubricants. The manufacture of illuminating gas, the electric light, and petroleum products have replaced to a large extent the use of animal oils for these purposes. However, lard oil has qualities as an illuminant and lubricant which still keep it in demand for such industrial uses. Neatsfoot oil from cattle is used for softening leather and weatherproofing, oiling watches and fine machinery, and lard oil is said to have no equal as a lubricant in cutting steel threads and in similar machine processes.

Some use is made of animal oils for lubricating textile machinery where the staining of fabrics by mechanical oils used to lubricate spinning and weaving machinery results in serious losses. Stained goods sell as seconds. Oil smears of this kind made by mechanical oils cannot be washed out as readily as can those from animal oils. Animal oils are also used in compounding with mineral oils for use on heavy machinery and in making high-grade cup grease.

The use of inedible fats and greases which are by-products of meat packing has closely associated the packing industry with the soap business. Anything like comprehensive treatment of this subject would occupy more of the reader's time than he may have the patience to indulge the author with, and it will be mentioned only briefly. Soap-making is not only a means of keeping human beings and their surroundings clean and

fit to live with and in, but it is also an outlet for fats and greases which can be used in no other way.

One of the by-products of soap-making itself is glycerine, which is constantly in competition with similar materials derived from mineral sources. The industrial use of glycerine for explosives was more or less disarranged by the development of nitro-cellulose products made of cotton linters and such things, and the glycerine market was correspondingly affected. Then an ingenious person connected with the soap industry had the happy thought of using glycerine in automobile radiators to prevent freezing in winter and this apparently put the glycerine market on a stable basis and saved the price of glycerine. Now comes ethylene glycol, a synthetic product derived from mineral sources, which threatens to put glycerine back where it was before. And the general use of air-cooled motor engines which may come within five years will still further complicate matters and give ethylene glycol as well as glycerine a run for a market.

The wide range in the uses of fats, oils and greases which the packer gets in the daily grind is shown by the fact that some fifty or more "end-products" from the original raw fat material are developed in the packing house alone, while many others are made by persons who buy this material from packers for further manufacturing.

In spite of the indispensable rôle of fats in the human diet, their use in animal feeding and the absolute necessity for oils and greases in the use of machinery, the chemistry of fats and oils is not nearly

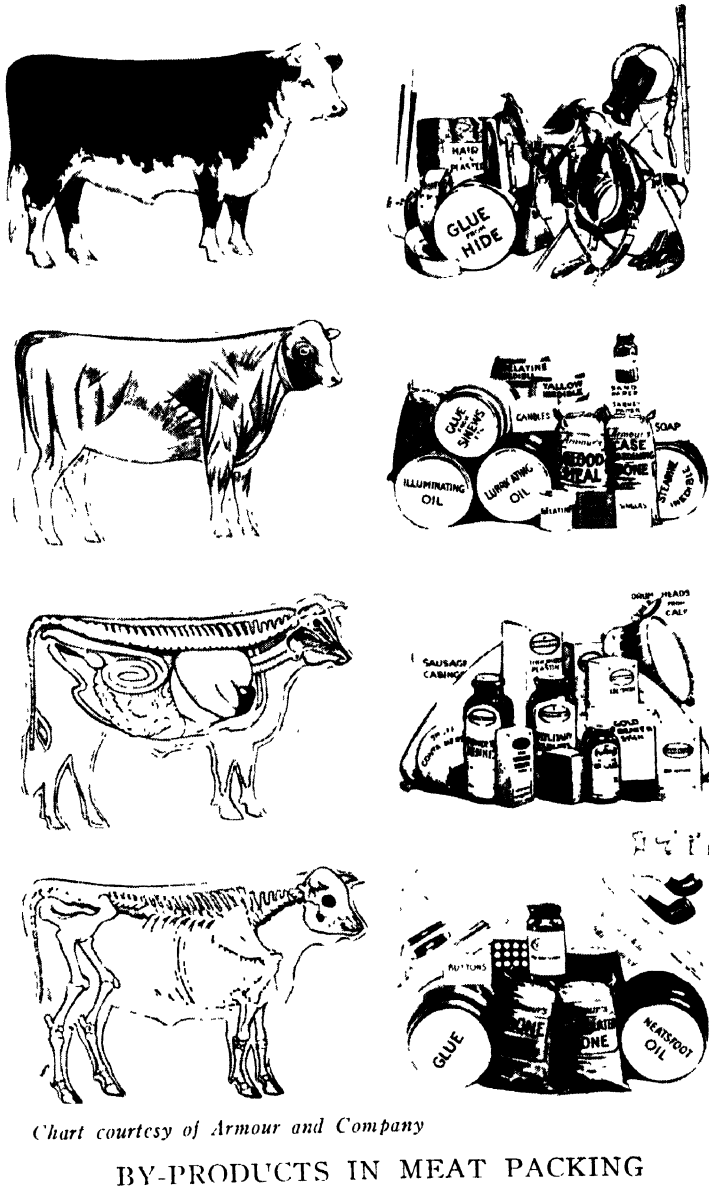


Chart courtesy of Armour and Company

BY-PRODUCTS IN MEAT PACKING

New uses are constantly being found for by-products--new wealth created--by the chemists of the packing industry.

Photograph courtesy of U. S. Forest Service

LAMBS ON MOUNT HOOD NATIONAL FOREST IN OREGON

The sheep industry in the United States has become stabilized by making lambs its main product, building up a steady demand for this main product and taking care of the by-product, wool.

so well known as that of many other subjects. The extremely complicated character of this branch of chemistry, the immense quantity of petroleum products available and their cheapness, the large amounts of cheap vegetable oils available from cottonseed, peanuts, cocoanuts, palmnuts, soybeans, flaxseed, sunflowers and a hundred other seeds from which oil may be extracted, if need be, has somewhat discouraged fundamental research in this field. The very abundance and variety of oils and fats make their chemistry a wonderful subject for research. A great deal has already been done, but much more remains in the realm of the unknown. It is a little too much to say that it is a wide open field, but it is certainly a very fertile one.

Wool:

The lesson which the packer has so well learned as to the value of by-products is being learned by most livestock men in this country, and by none more clearly than by sheep raisers. Raising sheep for wool alone has ceased to be profitable in the United States, but it is hard to get that idea into the heads of most people, and it took farmers themselves a long time to find out what was the matter with the sheep business in America. The trouble was that for many years most owners of sheep regarded their wool as the main product, and the animals themselves as the by-product. Every time any one said "sheep" most people at once thought "wool," farmers not excepted, when it should have been the other way around. Captain L. G. Connor showed this

clearly over ten years ago in an exhaustive study of the history of the sheep industry which was published in the annual report of the American Historical Association for 1918. Connor showed that the value of wool and that of other farm products had been steadily pulling apart since the Civil War.

Starting with 1861-2 they were equal, and Connor gave each a value of 100. In the period 1870 to 1884, farm products in general had gone up to 128; wool was 102. From 1885 to 1893, farm products were down to 102, while wool was 76. During the depressed years of 1894-97, farm products were 78 and wool 47. From 1898 to 1907 farm products were 104 and wool 73 and from 1908 to 1915 farm products were 143, while the best that wool could do was 79.

Of course these figures mean that most farmers would do better—make more money—out of other things than wool. Most farmers found that out, and the realization of the fact put a crimp in the fine-wool sheep business.

As soon as sheep owners began to concentrate on lambs as the main crop, with wool as the by-product, the sheep industry in the United States became more stable and more profitable. The demand for small cuts of meat has materially stimulated the lamb-raising industry and has tended to keep the prices of lambs stable. It may even have had something of an effect on beef prices, but the amount of lamb consumed is hardly large enough in any event to bring that about. It is clear, however, that, should there be any considerable increase in the volume of lamb produced to the

extent that it may become as important in our dietary as it is in England, the price of beef might be affected.

Certain it is that the lamb producer who regards his wool as a valuable by-product, taking good care of it, selling it intelligently through a good coöperative or in any other sensible way and not dumping it on the mercies of the local junk dealer, can make money from sheep, the wool paying his overhead and something besides, and the lambs being his source of profit.

We use some 600,000,000 pounds of wool annually in the United States, of which about half is imported. Of the 300,000,000 pounds which we import, approximately half is represented by the finer grades of clothing and combing wool, especially combing wool, both of which can be produced with intelligent management as a by-product of lamb production. There is no necessity therefore for radical adjustment in flock husbandry methods for the United States to meet its own demands for the finer grades of wool from its own resources. An increase in the demand for lamb in sufficient volume will automatically serve this purpose. The constructive work of the National Livestock and Meat Board is helping to bring this about, by calling the attention of customers to the advantage of lamb, and urging its purchase when the prospective buyer might pass up buying any meat at all.

It has been clearly shown that it is possible to produce wool of high quality simultaneously with profitable lamb production. The research work which has been carried on by the Animal Husbandry Division of the Bureau of Animal Industry at the United States

Sheep Experiment Station at Dubois, Idaho, presents perhaps the most complete information of this kind which has ever been obtained. The data were collected in the following manner: Each year at shearing time the fleeces were weighed individually, scored for fineness and a sample taken for the determination of grease and length of staple. The sheep were then scored to determine the closeness with which they approached perfect mutton type. The data obtained from the government station show plainly that there is no serious obstacle in the path of a flock-master's policy of combining mutton and wool production. There was no material difference in weight of fleece, length of staple or fineness of fleece between the wool production of ewes scoring 95 per cent on mutton type and those which only scored 55 per cent.

Still further data from the same source indicate what can be done with sheep that have been bred largely from the standpoint of wool production if due attention is paid to mutton qualities. Rambouillet sheep are more a dual-purpose sheep than other fine-wool breeds, and they are popular range sheep on account of this fact, their use helping to keep up the wool yield in a flock, and their well-known hardiness making the ewes good mothers.

Information furnished the writer by Mr. W. A. Dennecke, superintendent of the U. S. Sheep Experiment Station, illustrates this point nicely. These particular sheep, both ewes and lambs, were purebred Rambouillets, carried in the same band under identical conditions of feed, care and breeding for the three

years from 1925 to 1927. Ewes were handled on the range under recognized methods of good ranch practice. The lambs were weighed on the range early in August of each year, the weighing being done after the lambs had a twelve-hour shrink in a corral without feed or water. The total number of ewes was 890.

After these Rambouillet ewes passed the critical period of their first lambing on the range, the production of both lamb and wool increased steadily until they passed the age of five years.

The average weight of the lambs from the two-year-old ewes was just under 66 pounds, but the lambs from the older ewes averaged over 73 pounds, which is sufficient to meet market requirements. The average weight of lamb weaned for each ewe bred in the fall was only a fraction over 29 pounds in the case of the two-year-old ewes, but was 64 pounds for the five-year-olds. For the whole band of 890 ewes, including the two-year-olds, an average weight of 50 pounds of lamb was produced, worth 10 cents a pound, while the wool from the ewes in the flock averaged nearly 11 pounds each, worth, say, 35 cents a pound. So, with a lamb yield worth an average of $5 a year, the flock owner, our good Uncle Samuel, had a wool credit of less than $4. The lamb yield may be increased, and is increased by many commercial sheepmen, by managing the ewe band so that larger percentages of lambs are produced in proportion to the number of ewes bred and by management which obviates losses of lambs before weaning and thus increases the returns in pounds of lamb produced per ewe.

The lesson to be gained from this information is that in wool the sheep owner has a farm product used in industry which he may turn to his advantage when he has the right perspective of its proper place in farm economy. It is a by-product of great value when handled properly and marketed intelligently.

Other Livestock Production:

We might go into detail as to other lines of livestock production which illustrate the importance of by-product utilization in farming, but it would appear that the point is made with the illustrations given. The dairyman is often urged to pay more attention to the outlet in this country for casein, of which we import some twenty-odd million pounds a year. Casein is of great value in industry, but its production in the United States has never attained great importance. Perhaps the reason is that the dairyman is after bigger game. At any rate, dairy authorities, while pointing out that the daily production of skim milk, buttermilk and whey is "enough to float a battleship," and is mainly used for no other purpose than to feed animals, its value for human food is such that it should all be used for that purpose. That, indeed, is the aim of dairymen—to turn all dairy products to the best possible use, aiming at the market which pays best, which is the food market. The principle is sound, after all, for the complete utilization at the best possible price of all that comes to his hands is just as safe a rule for the farmer as for the manufacturer.

CHAPTER III

COTTON

The farmer who is in a position to dispose of some of his products in manufacturing industries is in a better economic position than the one who is dependent for his market entirely on the food demand, for the reason, enunciated in the introduction to this book, that the demand for food products is more or less inelastic, whereas the demand for the products of industry is elastic. Cotton farming is a most striking illustration of this fact. Cotton was exclusively an industrial crop, used in the process of manufacturing inedible things, until the discovery of the food value stored in the seed brought a new industry into being. The cotton farmer, with a money crop which can be stored indefinitely if need be, a crop in demand almost entirely for manufacturing, is in an almost impregnable economic position if and when he makes himself independent of the merchant, the banker and the fertilizer dealer. If he produces as much as possible of the food and feed requirements of his family and his livestock on the farm itself he will go far toward putting himself in this enviable category.

Cottonseed:

In one of the bulletins of the 12th (1900) United States Census a writer in a popular magazine was

quoted as saying: "Cottonseed was a garbage in 1860, a fertilizer in 1870, a cattle feed in 1880, and a table food and many things else in 1890." That writer would have been amazed at the use to which cottonseed is put to-day. The utilization of this by-product of cotton growing, cottonseed, has had a decided effect on the total value of the cotton crop in the United States. From an accumulation of waste utterly without value, except the small amount needed to plant the next crop, a waste often the subject of restrictive legislation compelling its disposal, an industry has developed which has been estimated to produce value in its manufacture equal to $500,000,000 a year. The average annual valuation of cottonseed on farms approaches $200,000,000, which shows that a considerable portion of the total value of this great industry finds its way back to the farms on which it originated.

Entirely aside from the food value of the oil and the feed value of the cake, to which may be ascribed a considerable portion of the value of cottonseed, and therefore not to be discussed in these pages under the rule laid down by the author, the purely industrial uses of this product are of the highest importance. Mr. G. S. Meloy, of the Department of Agriculture, points out that as a result of the application of chemistry to the utilization of cottonseed, not only have the food and feed values been highly developed, but the oil is put to important industrial uses, including miners' lamp oil, soap and soap powders, glycerin, which is used in many ways, including the manufacture of nitroglycerin, and pitch which is used in the manufacture

of roofing paint and composition roofing. The cake is used as cattle feed and fertilizer, while the linters, entirely inedible by man or beast, are put to a wide range of use in manufacture, and even the hulls are coming into use for something beside cattle feed, as we shall see later.

The production of cottonseed in the United States for the past five years according to the yearbooks of the United States Department of Agriculture was as follows:

COTTONSEED AND COTTONSEED PRODUCTS IN THE UNITED STATES

Year beginning August, 1922-1926.

(000—Omitted)

Year	*Production Short Tons*	*Total value Dollars*	*Cottonseed Crushed Short Tons*	*Oil Gallons*	*Cake and Meal Short Tons*	*Hulls Short Tons*
1922	4,336	150,445	3,242	133,723	1,487	944
1923	4,502	190,110	3,308	130,616	1,518	941
1924	6,051	206,190	4,605	187,171	2,126	1,331
1925	7,150	220,381	5,558	215,602	2,597	1,547
1926	7,989	172,134	6,306	251,721	2,840	1,854

Cotton Linters:

The development of the market for cotton linters is one of our famous American industrial romances. After cottonseed got itself comfortably established as a source of oil and cattle feed in 1900, the fuzz on the seed became almost as much of a nuisance as the seed itself had been forty years before. It was never a garbage or a cattle feed and it was not destined to be developed into a table food. It was just a bother.

Industrial chemists and inventors then got busy on this fuzz. Machines were devised to "de-lint" cottonseed and this product became known as "cotton linters," with a limited market for mattress stuffing and cotton batting and worth no more than 1 cent a pound. The de-linting machines took twenty-five pounds of linters to the ton of cottonseed in 1900 and ten years later the amount removed was double that figure.

That put the cottonseed oil trade between the devil and the deep blue sea so far as cotton linters were concerned. If too much lint was taken off the decortication of the seed was difficult and the expense of the operation frequently ran up beyond the value of the linters. If not enough linters were removed, those remaining would absorb oil in the crushing process and thereby cause a loss, and the fuzz would get into the cake, reducing its quality and value.

Then came the War. The demand for cellulose for explosives and for other things into which cellulose might be manufactured turned industrialists to this abundant supply of cheap raw material, 85 per cent of which is cellulose. The price of linters went skyward until Uncle Sam put his foot on it and held it at 4½ cents a pound. When our Uncle relaxed his control after the Armistice and the lid blew off, choice cotton linters soared in price beyond 14 cents.

Again Uncle Sam stepped in, and in 1925 he established official standard grades for American cotton linters, with the approval of cotton trade associations.

The pariah of twenty-five years ago is now a respectable and much-sought-after member of industrial

society. It was chemists who found out how to turn cotton linters into more valuable things than mattress stuffing and cotton batting; it was chemists who found other things to do with cellulose besides blowing all creation to kingdom come with high explosives.

As a result of chemical research the beautiful lacquer finish on your new car, as well as its water-tight top and perhaps its upholstery; leather substitutes, toilet articles of all kinds, such as brushes, combs, mirror backs, toothbrushes; kodak and movie films; sausage casings, rayon and fine paper are now made out of a cotton product that almost went begging twenty-five years ago. Even in trouble, disaster and death, cotton linters help to ease the way, for sterilized gauze and "new skin" or collodion, made from them, are indispensable in the sick room.

Cotton linters have become so valuable that the seed is sometimes scraped as if it had been shaved with a razor. No longer does the cottonseed man worry about taking off too much or not enough. He makes the "first cut" with his delinting machine, which produces the highest grade of cotton linters.

These "first cuts" or "first-cut linters" are those cuts which run from 25 to 50 pounds to the ton of cottonseed. "Mill runs" are cuts running from 35 to 100 pounds or more per ton of seed, and are also spoken of as "mill-run linters."

After the first cut is made cottonseed is often run through the delinting machines a second time, especially if less than 35 pounds of linters were removed by the

first cut. On the second cutting from 30 to 200 pounds of fiber may be recovered.

This usually completes the cutting, but after the seed is decorticated and the hulls are removed from the kernels, a final effort is sometimes made to save the last bit of lint by running cottonseed hulls through special machinery. This results in the recovery of "hull fiber," which falls into the lowest of the seven official grades for cotton linters. The woody substance of cottonseed hulls then remaining is known to the trade as "hull bran." This product contains cellulose and other chemical constituents which promise to be the basis of a budding industrial romance to be related in the next section.

The amount of cotton linters produced is growing rapidly as we see from the following official figures:

Year beginning August	*Production in 500 lbs., gross weight bales*
1922	607,779
1923	668,600
1924	897,375
1925	1,114,877
1926	1,157,861

Cottonseed Hulls:

Only the hulls of cottonseed are "useless," but the cattle feeder finds them valuable to feed with cottonseed meal and the feed manufacturer uses "cottonseed bran" as filler. It cannot be said, however, that the utilization of cottonseed hulls has reached its greatest economic possibility. With a production which in some

years, as in 1927, reaches almost two million tons, the local demand for cattle feed fixes the price, which fluctuates widely, having been as low as $2 a ton at some cotton oil mills in 1927 when thousands of tons of hulls were burned under boilers.

Cottonseed meal and hulls have been for years a standard cattle ration in the Cotton Belt. Hulls in such a ration have merit as feed, giving the ration bulk and balancing the richness of cottonseed meal. Fed alone, cottonseed hulls will keep cattle from starving, but little more. Large amounts were bought at very high prices by Texas ranchmen during the drouth ten years ago.

But whatever may be said about the hulls themselves as cattle feed, no claims at all can be made for the feed value of the fuzz which sticks to them even after the linters have been cut twice. This fuzzy material is actually cotton lint, and no one would think of feeding cotton lint to his cows. Cattle require a bulky ration. They eat hurriedly and digest at leisure, bringing up for a second chewing balls of food from the paunch to be thoroughly masticated and re-swallowed. When their food is not only bulky, but succulent and digestible, cattle grow fat; when it is only bulky they grow thin. A bulging middle piece does not necessarily indicate a fat animal; more often it shows the opposite. Cattle do not chew the cud for the reason that flappers or tired business men chew gum.

There is nothing in the idea that the fine lint fibers on cottonseed hulls "make a good cud." The best cud a cow can get comes from a rich pasture, as any one can

see by watching the improvement in condition of cattle on pasture when grass gets good in the spring. Then watch them go off in condition during a hot dry spell in late summer, when grass loses its succulence, dries up and gets woody, and you see what mere bulk does to them. Bulk alone does not "make a good cud." There must be succulence and digestibility also. Neither of these qualities is found in cotton fiber. Cotton hulls are not at all succulent and they are low in digestibility, so that, taking lint and hulls together, as we find them in ordinary cottonseed hulls, they are by no means an ideal cattle feed.

Every successful stock feeder knows that a feed showing a high analysis of "crude fiber" has low nutritive value. Crude fiber is practically all cellulose, which the feeder avoids as much as possible, but which manufacturers are now using in constantly increasing quantities.

However, the very qualities which give cottonseed hulls a low value for cattle feeding make them valuable as a raw material for manufacture because of their high content of cellulose.

Cotton fiber is almost pure cellulose and even cotton linters are little lower in value than lint cotton in this respect. The fuzz on cottonseed hulls, called "chemical cotton" when it is separated from the hulls by a chemical process, promises to become highly valuable for chemical manufacture.

Cottonseed hull bran has been analyzed by Mr. K. S. Markley, of the United States Bureau of Standards, with the following results:

	Per cent
Moisture	12.27
Ash	2.09
Crude fat	0.80
Crude protein	2.88
Crude fiber	32.49
Nitrogen-free extract	49.47
	100.00

The following separate yields of chemical substances can be obtained from cottonseed hull bran.

	Per cent
Nitrogen	0.46
Furfural	22.23
Pentose	43.14
Pentosan	37.96
Lignin	20.91

The nitrogen-free extract in cottonseed bran contains 37.59 per cent of sugar calculated as dextrose or 38.24 per cent calculated as xylose, according to Mr. Markley.

It would seem from these figures that cottonseed hull bran is more valuable to the manufacturer than to the livestock man, and the southern cattle man would probably save money if he depended for his roughage on the wide variety of legume hay and the succulent pasture which he can produce, leaving cottonseed hulls entirely to the manufacturer. In other words, the chemical composition of cottonseed hulls indicates that they are worth more to turn into manufactured cellulose

products than to feed to cattle, provided means are developed which make them profitable to manufacture.

In a later chapter in this book consideration will be given to the utilization of cornstalks for manufacturing purposes. It now appears that the cottonseed hulls of the South have joined the northern cornstalks in commanding industrial attention. While Government scientists, working under a Congressional appropriation to discover ways of utilizing farm waste, have been centering their research on these materials, private initiative appears to have perfected processes for handling both on a commercial scale. The Cornstalk Products Company, which is responsible for the first cornstalk cellulose plant in the United States at Danville, Illinois, recently announced that its chemists have also perfected a process for converting cottonseed hulls into cellulose and many valuable by-products.

The new process is said to differ radically from any heretofore used in attempts to salvage the values known to exist in cottonseed hulls, because the separation of the lint from the hulls is brought about by a chemical rather than by a mechanical process. When the lint is separated from the hulls mechanically the disintegrated short fiber produced—hull fiber—sells as the lowest grade of cotton linters for 2 or 3 cents a pound. The highest grade of cotton linters sells for 8 to 12 cents per pound.

Rayon manufacturers and others in the chemical cellulose industries, even when using the highest grade of cotton linters as raw material, must purify them chemically, and the paper-maker must bleach them.

This processing and the resulting shrinkage add considerably to the cost of the raw material.

The new process of the Cornstalk Products Company is said to produce a "chemical cotton" of short fiber but of uniform quality and length, pretreated chemically and ready to go into solution for the rayon and other chemical cellulose industries, or, without further bleaching, into the manufacture of paper. The company's chemists state that for these purposes this new product, on account of the chemical treatment to which it has already been subjected, will be superior to the cotton linters now purchased.

It is also stated that if all the cottonseed hulls in the United States were treated by the company's new process not less than 250,000 tons of "chemical cotton" could be recovered from the average year's crop of cottonseed hulls, and that the other recoverable chemical products include a superior grade of cellulose flour which promises to be a more satisfactory product for use in industry than wood flour. The proportion is said to be about 1½ tons of cellulose flour to one ton of "chemical cotton."

When the new process comes into general use, cottonseed hulls will no longer be classed as a waste farm product.

The attractive possibilities in the use of cottonseed hulls from the standpoint of the manufacturer lie not only in what chemists and technologists may do with the cellulose and by-products but in the accessibility of the raw material. Every cottonseed oil mill produces large quantities of hulls during each day of operation

which largely eliminates the cellulose manufacturer's collection problem.

Cotton Stalks:

The possibility of using cotton stalks as a source of raw material for the manufacture of wall board or for cellulose pulp is frequently mentioned. There is no doubt that in proportion to the total weight which a farmer produces in growing a crop of cotton, an enormous loss occurs in the stalk and other unharvested parts of the plant. Exact data on this point are not so general through the Cotton Belt as we find in the case of by-products of grain production in the Corn Belt. The cotton grower is interested only in the money-producing part of his crop which is seed cotton, just as the corn grower or the grower of wheat or other small grain places the most emphasis on the grain produced. The cotton grower does not as a rule gather any portion of the stalk in picking his cotton and for this reason experimental data on cotton growing at southern agricultural experiment stations contains very little information on the production of anything except seed cotton. However, we find in Bulletin 247, by Prof. G. S. Fraps, of the Texas Agricultural Experiment Station, published in 1919, a report of a study of the chemical composition of the cotton plant in which he gives figures showing the production in weight of stalks, leaves, bolls and burs per acre as well as that of seed cotton.

From this study by Dr. Fraps it would appear that for every pound of seed cotton produced in Texas a

Photograph courtesy of U. S. Dept. of Agriculture

A COTTON FIELD IN TENNESSEE

Cotton, our great industrial crop, has been greatly benefited by the development of new outlets in chemical manufacturing as well as in the textile industries.

Photograph by Beery

SLEDDED COTTON IN WEST TEXAS

Harvesting cotton with sleds accumulates large quantities of waste material which may be utilized for the cellulose and other carbohydrates which it contains.

much greater weight goes into the stalk and other parts of the plant. For example, Mebane cotton grown at Beeville produced 1,170 pounds of seed cotton per acre and 1,330 pounds of stalks, with additional weight in the leaves and burs. The same variety grown at Temple produced 804 pounds of seed cotton and 1,065 pounds of stalks. At Troup this variety produced 730 pounds of seed cotton and 1,664 pounds of stalks. At Nacogdoches Mebane cotton produced 1,113 pounds of seed cotton and 1,372 pounds of stalks. At Denton a local variety of Mebane cotton produced 967 pounds of seed cotton and 2,126 pounds of stalks, while at Lubbock, in "West Texas," Mebane cotton produced 389 pounds of seed cotton per acre and 446 pounds of stalks. These yields of cotton stalks are much less per acre than we will find later on to be the case with cornstalks.

The rather high content of fertilizing constituents found in cotton stalks has been urged by many authorities familiar with the cotton-growing industry as a reason why they should not be used for manufacturing but should be returned to the soil in order to conserve this fertility. So far as phosphoric acid and potash are concerned, this objection is probably well founded, but in the case of nitrogen it is not true as we shall see later in the discussion of the fertility value of cornstalks. In some sections the removal of cotton stalks from the field or their destruction by burning is found to be good farm practice, because they carry over from one season to another the organism which causes cotton

root-rot; the removal of the stalks before the new crop is planted is thus based on sound scientific principles.

However, it should be pointed out that heavy stalk production in the cotton plant and boll-weevil control are antagonistic. The trend in cotton growing is toward the quicker-maturing lower-stemmed varieties in order to get the crop matured before there is great danger of boll-weevil damage. This will probably tend to produce a lower tonnage of cotton stalks per acre.

Waste from Sledded Cotton:

The practice of sledding cotton which developed with such amazing suddenness in the Southwest in 1926 was hailed as the greatest fundamental change in the methods of growing cotton and making it available for the manufacturer since the invention of the cotton gin by Eli Whitney in 1793. If this practice should become general throughout the Cotton Belt, the inventor and the chemist will find an enormous amount of new waste material on which they may exercise their ingenuity. In the process of sledding cotton, the burs, parts of the stems and some leaves are pulled off with the seed cotton and find their way to the gins. It has been estimated that 1,000,000 bales of lint cotton were harvested by sledding in Texas and Oklahoma in 1926. The amount of hand-picked cotton required to turn out a 500-pound bale of lint cotton in West Texas averages 1,300 to 1,400 pounds, and in Oklahoma from 1,500 to 1,600 pounds. The usual range of sledded cotton in this region for one 500-pound bale of lint cotton was found to be from 1,800 to 2,200 pounds by A. P.

Brodell and M. P. Cooper, who studied this subject for the Texas Agricultural Experiment Station and the United States Department of Agriculture in 1926 and 1927.

This greater weight of sledded seed cotton compared with hand-picked seed cotton is the trash collected by the sleds. It is not a new cotton product at all; heretofore it has always been in the fields ungathered. Now it is piled up alongside the cotton gins in the territory where sleds are used—a by-product of cotton growing which thus far has no value. Taking the figures of Brodell and Cooper, it may be estimated that from 250,000 to 400,000 tons of this waste material were piled up around the cotton gins in the Southwest in 1926. The available amount will vary according to the extent to which cotton is harvested by sleds. In 1927 very little cotton was harvested in this way because the price was much better than in the previous year and labor was more abundant.

The Bureau of Chemistry and Soils of the Department of Agriculture reports a laboratory yield in furfural from sledded cotton waste of 9.8 per cent.

The bulk of this sledded waste is cotton burs, an analysis of which, made by the United States Bureau of Standards, shows the following amounts of cellulose:

Total Cellulose	
Air-dry	42.8 per cent
Oven-dry	47.2 per cent
Alpha Cellulose	
Air-dry	29.2 per cent
Oven-dry	33.0 per cent

This waste material may be made to yield large quantities of furfural, alcohols and other solvents and should make good raw material for wall board. With the spread of the practice of sledding cotton, we may expect to see an increase in quantity of such material piling up each year. If the suggestion of Mr. O. F. Cook, of the Department of Agriculture, should be followed and cotton should be harvested by a binder as grain is now harvested, there would certainly be a large amount of such material available. Mr. Cook suggests taking the bundles to a central point where they would be run through a picking machine which would pick and clean the seed cotton, throwing out the remainder as refuse.

New Uses for Cotton:

The United States has suffered four serious cotton slumps in twenty years—in 1908, 1914, 1920 and 1926. The primary cause of each one was the same—more cotton than the market would take at the time and at the prices that prevailed for preceding crops.

Curiously enough, just about the same amount of surplus cotton did the trick in each case and an increase of about two million bales in each surplus-slump year threw the cotton marketing machinery of the whole country out of gear and forced thousands of cotton growers into the hands of the money sharks. Each was a pitiful exhibition of the great fire caused by a tiny spark. The increase in the crop of 1908 over that of 1907 was only 19 per cent; of 1914 over 1913, 13 per cent; of 1920 over 1919, 18 per cent, and

of 1926 over that of 1925, only 12 per cent. The 1908 slump was least disastrous of all, and the average price of New Orleans spots receded only 12 per cent in that year, but in 1914 the price drop was 36 per cent of that of the preceding year, in 1920 it was 57 per cent, and in 1926 it was 25 per cent. The market recovered within a year after the 1908 slump as it did after 1926, but in the two other instances two years or more were needed to bring prices back enough to cover normal production costs and leave a profit to the producer.

Various relief measures have been proposed during these four hectic periods in twenty years of cotton history. Bales were bought and bulls were bartered to no effect, but farmers took things into their own hands and reduced production. Whether that was economically sound or unsound is beside the point; it was human, and it was done. Just as human is the clear realization of the fact that, in spite of its upsets and rebounds, cotton is the greatest money crop that the Southern farmer has. His chances of making money with it are greater than his chances of losing; therefore he sticks to cotton.

The wise men have brought several new angles into the discussion of what to do to prevent occurrences of these cotton slumps. The first is growers' organizations. Farmers are attending to that pretty well, and they will prevent such things as happened two years ago if and as they stick to their coöperatives, if they use the same intelligence in handling their coöperative business that a successful cotton merchant does, and

if they pay the market price for such intelligence. It comes high, but it is worth it and growers are realizing that fact.

How far can we carry the utilization of cheap cotton? How can we get low-grade cotton manufactured into something at a price that lets the grower at least break even, and gets it out of the market so that it does not depress the price of high-grade cotton? There is nothing unreasonable in that idea. The same principle has been applied successfully all over the country in the market-milk business and is responsible for the stability and profitableness of that branch of farming.

Why not wrap our cotton bales in cotton bagging? That question recurs with every cotton slump, and every time we have a tremendous cotton crop in America, there is also a tremendous demand for jute bagging and the price of jute bagging goes up while the price of cotton that is put up in it goes down.

Jute and jute manufactures compete with cotton in the domestic market. They are imported in large quantities and are used extensively instead of cotton, not only as bags, but as bagging for cotton itself, and, in the form of burlap, for wall coverings, linoleum backing, and so on. The money the United States spends for jute is growing rapidly. Although the value of jute imports declined in 1927, they were considerably higher in 1927 than the average of the years 1921-25, and more than double the value of the average annual pre-war imports. From 1910-1914 the value of net imports (imports less exports) averaged $39,600,000 a year; in 1921-1925 they averaged $73,800,000 a year,

in 1926 they were $109,700,000, and in 1927 they were $86,415,000.

Cotton makes quite as satisfactory bagging as jute, but it cannot yet compete in price. Jute and jute products imported into the United States averaged in value as follows:

JUTE—UNIT VALUES OF IMPORTS

Jute and Jute Butts

Year ended Dec. 31	*Per ton of 2240 lbs.*	*Per Pound Cents*	*Jute Burlap Per Pound Cents*
1923	$128.33	5.72	11.2
1924	114.02	5.09	10.3
1925	190.69	8.51	13.6
1926	214.44	9.57	13.7
1927	132.50	5.92	11.8

These prices represent the value of the goods in the foreign market whence they are exported to the United States and charges of delivery to American ports must be added to them. Most of the jute imported into the United States is in manufactured condition and comes from India. Prices f.o.b. New York on jute, long fiber (3 to 6 feet long) were quoted in early December, 1927, at 6½ to 8¼ cents per pound. Jute butts (short lengths, from 5 to 12 inches) f.o.b. New York were 4¼ to 4.35 cents per pound. Jute butts have been offered recently at New York at 3½ cents per pound, which is said to be more nearly the normal pre-war prices than have been quoted on jute since the war. During the spring of 1928 prices advanced somewhat. In May quotations at New York were: long fiber jute, 8 to 9½ cents per pound; jute butts, 5 to 5¼ cents per pound.

In the process of marketing the cotton crop, the equivalent of about 200,000 bales of cotton goes into jute bagging in this country every year. That, however, is only a small part of the jute bagging used. The grocery trade takes an amount of jute for bags which is equivalent to some 800,000 bales of cotton and the feed and fertilizer business takes an additional amount. It would therefore appear that the amount of cotton we would consume in the United States if all the jute we use were replaced with cotton would be well over a million bales, which would be more than half of the amount of surplus cotton which was largely responsible for the drop in prices during the four years that prices slumped.

The agitation to replace jute with cotton bagging grown in America is by no means new. It was extremely active forty years ago when some 4,000,000 yards of Odenheimer cotton bagging were manufactured. The difficulty then, as to-day, was the comparatively high price of cotton and the comparatively low price of jute.

The most intelligent effort yet made to solve this problem is now under way under the leadership of Dr. Bonny Youngblood, who is in charge of cotton marketing research in the United States Department of Agriculture. Dr. Youngblood gives as the reasons for considering cotton bagging in preference to jute "the desirability of removing from the channels of trade vast quantities of low-grade cotton which tend to depress prices; of reducing the weight of bagging; of standardizing the weight of bagging; and of putting

cotton up in neater packages and handling it in a less wasteful manner than has been the common practice in America up to this time."

The first thing Dr. Youngblood started out to do was to determine the quality of cotton bagging compared with new 2-pound jute. He made four patterns of bagging, weighing 12, 16, 20 and 24 ounces per linear yard, 45 inches wide, and one of heavy patching material weighing 16 ounces per linear yard, 30 inches wide.

The lightest of these patterns, weighing 12.3 ounces per square yard, had a breaking strength of 79 pounds in the warp and 112.8 pounds in the filling, compared with 60 pounds in the warp and 50.4 pounds in the filling of the new 2-pound jute. The famous "Egyptian" jute bagging showed a breaking strength of 53.1 pounds in the warp and 66.3 pounds in the filling. Furthermore, there was greater elasticity in the cotton patterns than in the Egyptian jute bagging, and in the compress cotton bagging withstood the strain well, while the Egyptian bagging was often cut by the bands when the bales were taken out of the compress.

Dr. Youngblood then put up 120 bales of cotton at Henderson, North Carolina, for shipment to Europe. Twenty-four bales were baled in 2-pound jute and 24 in each of the four patterns of cotton bagging. They were shipped to Norfolk, Virginia, weighed, sampled on both sides, compressed, and then shipped to Bremen, Germany, with a commercial shipment of 2,275 bales, the experimental bales being handled in the same manner as those in the commercial shipment. When the cotton arrived in Germany, the bales put up in jute and those

in the lightest weight cotton bagging were in about the same condition and both were ranked as "normal." Those put up in the heavier cotton bagging were 15 per cent, 50 per cent and 75 per cent above normal respectively. The experimental cotton was then loaded on the same steamer and shipped back to America.

As a result of these tests Dr. Youngblood concludes that from the standpoint "of durability, protection to the cotton and neatness, cotton bagging is a more suitable covering for the American cotton bale than is jute."

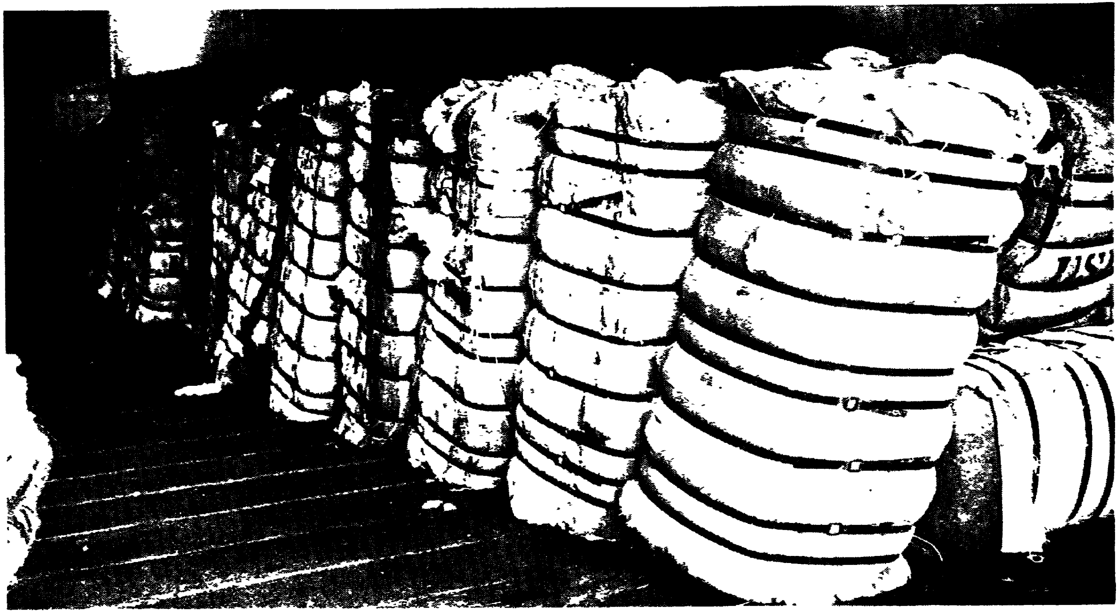
That ought to settle it if we could eliminate the little detail of cost. When Good Ordinary cotton is worth 4 cents a pound, the price of Youngblood's lightest weight pattern (fully equal to 2-pound jute) would be 61 cents, and when Good Ordinary cotton is worth 15 cents a pound it would be $1.25. Only once in the past five years (in 1926) have the relative prices of cotton and jute been such that this particular pattern of cotton bagging could be made in competition with that of new 2-pound jute. In 1926 the light-weight pattern would have cost 98 cents, and one from 2-pound jute $1.14. In 1925 a 6-yard pattern of this cotton material would have cost $1.50 and one of 2-pound jute 96 cents. In 1923 the difference would have been still greater, with the jute bagging at 54 cents and the cotton bagging $1.89. For the heavier weights of cotton bagging, the price was prohibitive.

But that isn't all. In 1927 at Shreveport, Louisiana, a mill started in to make a half million yards of light-weight cotton bagging on the Odenheimer pattern.

Photograph courtesy of U. S. Dept. of Agriculture

TWO TYPES OF COTTON SLED

These implements run on skids and are hauled through the fields by horses, mules or tractors. The cotton bolls are pulled through the slots or "fingers" and drop off into the box. The sled at the left is used where cotton is over 30 inches high. The one at the right is used principally when cotton is less than 30 inches in height.



Photograph courtesy of U. S. Dept. of Agriculture

COTTON BALED FOR EXPORT IN COTTON BAGGING

Experiments by the Department of Agriculture show that cotton bagging is fully equal to jute in every respect except that of cost. The best thought in the cotton industry is being devoted to the question of using low-grade cotton for such purposes.

Farmers liked it and were willing to pay the higher price for it. But a cotton bale put up in this cotton bagging weighed 7 pounds less than a cotton bale in jute bagging. As cotton is sold on gross weight, that penalized the farmers using the light-weight cotton bagging and they objected strenuously to being made to stand for the 7-pound difference in the weight of the bales put up in cotton bagging. With jute bagging costing 36 cents a bale less than cotton bagging and cotton at 20 cents a pound, this meant that farmers using cotton bagging paid $1.76 for the privilege.

We now approach the subject of the tariff. A tariff is not worth anything to plain producers unless it works. A tariff on jute which would work well enough to bring cotton into general use for bagging would have to be high enough to make the price of raw jute and low-grade cotton practically equal in this country, say at New York, New Orleans or any other market. Assuming that it costs no more to manufacture bagging out of cotton than out of jute, a manufacturer wouldn't care which fiber he used if he was sure some competitor would not cut the ground from under his feet by having a supply of cheaper raw material; the tariff presumably would take care of that.

There is a tariff on manufactured jute imported into the United States, but jute fiber and jute butts come in free of duty. It would appear from the figures given on page 69 that the grower in India can afford to raise jute, ship it halfway around the world and sell it in New York at 4 to 5 cents a pound. No cotton grower would raise cotton at these prices under present methods

of hand picking. So it appears that the amount of protection needed to bring the price of jute in America to a parity with that of low-grade cotton would have to be very high. If a tariff should be put into effect and the growers in India faced the danger of losing their golden American market on that account, they might still be able to raise jute, ship it here, pay the tariff and undersell our cheapest cotton on account of the low scale of living among farmers in India.

Still more complications loom against a tariff. Jute is used for many things besides cotton bagging and some authorities believe that an effort to meet jute competition with cotton bagging by means of a tariff on jute fiber might cost farmers more than they would gain, on account of the higher price that other kinds of bags would cost. We have seen that the amount of bagging made of jute and used for cotton bales, grocery bags, sugar bags, fertilizer and feed bags is the equivalent of more than a million bales of cotton a year. If we change from jute to cotton bagging by means of a protective tariff, all bagging would cost more, not only bagging for cotton the farmer sells, but bagging for a dozen things he buys,—feed, fertilizer, sugar and a wide range of groceries. Of course, the purchaser of such supplies would have to pay that bill.

These are the arguments commonly urged against a protective tariff on jute fiber. However, economists have estimated that if the 200,000 bales of low-grade cotton required for cotton bagging were actually so used, the price of all cotton grown in the country would be increased ½ cent a pound or $2.50 a bale. On a

15,000,000-bale crop that would amount to $40,000,000 a year. Add several hundred thousand bales additional for other bagging to replace jute and as much as $150,-000,000 might be added to the annual value of the cotton crop. That is not a bad target to shoot at, if there was no chance of killing a lot of innocent by-standers.

The easiest way to dismiss any subject is to say it can't be done. With cotton admittedly superior to jute as raw material for bagging, there should be a way to use it profitably for the purpose, either by using low-grade cotton already produced or by growing cotton especially for the purpose where it can be grown cheaply, or by a tariff or by a combination of these three methods.

It is not necessary to drive jute out of our markets in order to use much larger quantities of low-grade cotton than are now manufactured. Dr. Louise Stanley, Chief of the Bureau of Home Economics of the Department of Agriculture, has shown how cotton bagging can be made into floor rugs, bath mats and even portieres and window hangings. The possibilities of such uses as these are incalculable for the amount of cotton which might be used in this way is only limited by the demand for attractive things for the home. Cotton bagging such as that which Dr. Youngblood made for cotton bales can be used for upholstery if a way is hit upon to prevent the lint from shedding. That ought not to be difficult; it has been done with cotton twine which has no superior for many uses and which does not de-lint in use.

Still other uses for low-grade cotton may be found in such fabrics as the light cotton bagging material known as "Osnaberg." These fabrics are very cheap and they can be made into beautiful things for home decoration by using a little art in their manufacture. In fact these materials are already being offered for such purposes in many dry goods stores.

The amount of money which the United States spends abroad every year for imported cotton fabrics is considerable, as we see from the following table:

IMPORTS OF CERTAIN COTTON MANUFACTURERS
1922-1926

Year	*Cotton Cloth*	*Cotton Fabrics*	*Total*
1923	47,188,000	2,494,000	49,682,000
1924	37,703,000	3,709,000	41,412,000
1925	26,424,000	5,233,000	31,657,000
1926	16,258,000	7,751,000	24,009,000
1927	15,594,000	9,136,000	24,730,000

Many items in imported cotton manufactures are hand-made articles which do not fit in well with our industrial methods, but most of the cotton cloth noted above is unbleached, for which we paid about $5,000,000 last year, and colored, dyed, printed and woven figured material which cost us $8,000,000 more. Osnaberg cloth is made of low-grade cotton; it is strong, durable and cheap and makes beautiful curtains, hangings and couch covers. Properly made, it compares well with the best imported cretonnes. In its humbler phases, it serves nicely for upholstery backing.

A use for cheap cotton which has attracted much attention but which seems to be still in the experimental

stages is the use of "Cider Duck" for road construction. This has been done in South Carolina. The road is graded and rolled and tar is then poured on the surface. While the tar is still sticky, the duck is placed on it and asphalt is then poured over it. This material is loose-woven stuff, with about 4 threads to the inch, and weighing about 7 ounces to the yard. It is said that bids have recently been called for some 300,000 yards of it for road work.

Certain it is that if the low-grade cotton produced in America can be sold well, no grower need worry about the higher grades. How will this be done? The answer calls for the best thought that can be given it.

Lower Costs of Cotton Production:

To make the production of cheap low-grade cotton profitable the American cotton grower must be able to produce his cotton at much lower costs. He can do that with the sled. Brodell and Cooper's data on the sledding of cotton in the Southwest in 1926, already referred to, show striking contrasts in costs of harvesting with sleds as compared with hand-picking.

Labor requirements for hand-picked cotton and sledded cotton in 1926, for each 500-pound bale of lint cotton, were as follows:

	Hobart, Oklahoma *Man hours*	*Lubbock, Texas* *Man hours*
Hand-picked cotton	68.2	48.7
Sledded cotton	8.5	5.3

A much smaller amount of cotton was sledded in 1927 than in 1926. The price was better, labor for

picking was more plentiful and growers could afford to pay the higher cost of hand picking in order to command the higher price for hand-picked cotton.

The need of a satisfactory method of dispensing with the hand-picking of cotton is obvious. No new development in agricultural engineering promises such rich rewards for its inventor. Mr. Cook's suggestion is worth thinking over.

Improving the Quality of American Cotton:

Brief mention should be made of the elaborate research program under way in the Division of Cotton Marketing of the Bureau of Agricultural Economics. This program is being conducted in close coöperation between the Bureau of Home Economics, the Bureau of Foreign and Domestic Commerce, the Bureau of Standards, the Cotton Textile Institute, cotton growers and cotton manufacturers. Certain striking facts have been already developed. A preliminary list of uses to which American raw cotton is put covers twelve pages of a mimeographed report. Farmers alone use 150 articles made partly or wholly of cotton, in addition to wearing apparel and household articles.

It is a regrettable fact that the increase in labor costs for picking cotton has been responsible for a lower quality of cotton received at the gins from farmers. Cotton now contains so much trash that gins have been compelled to install cleaning machinery. This adds to the cost of ginning and is a direct charge against the crop. It is also an incentive for the invention of a practical cotton-picking machine.

The production of short-staple cotton with lengths of 13/16 inch and under is not profitable because only a small proportion of this cotton is used in the American textile industry, and the remainder must be exported to foreign markets where it competes with short-staple cotton produced by low-class, poorly paid labor. A survey by the Bureau of Agricultural Economics in co-operation with the Georgia Experiment Station showed that in 1927 Georgia farmers produced 23,197 bales of this short-staple cotton. This is more short-staple cotton than all the mills of the United States consume in a year. Mills are now demanding certain lengths of cotton in their purchases, discriminating sharply against the short-staple cotton mentioned and also against cotton of unusually long staple, which knots and breaks in spinning, thus adding to the manufacturing cost.

Dr. R. W. Webb, of the Cotton Marketing Division of the U. S. Bureau of Agricultural Economics, is having gratifying success with the use of the Baer sorter for determining the various staple lengths in which the fibers in a given cotton sample will fall. It is obvious that the most valuable cotton for a spinner to buy is that in which the greatest proportion of the fibers falls into staple lengths best adapted for his spinning. This subject presents a useful field for the plant breeder. Dr. Webb has found that some varieties of so-called purebred cotton fall far short of manufacturing requirements.

CHAPTER IV

THE FOREST SITUATION

ONE of the most interesting phases of the author's study for the United States Secretary of Agriculture of the industrial utilization of farm products, out of which this book has developed, was the information on the production of cellulosic material, of which wood, of course, is the main source. A sincere effort was made to get dependable facts and to present them without bias, leaving conclusions largely to the reader's deductions. At the risk of violating his cautious policy, the author will make an emphatic and dogmatic statement right at the outset of this chapter. The old-time lumberman who looks on his business as just felling trees to cut into saw-logs to turn into lumber as fast as he can, to sell if he can in standard 16-foot lengths is doomed, unless he changes his thinking and mends his ways. This chap is the source of the gloom which pervades the lumber business. He sees the handwriting on the wall, but he can't read it. And, like anybody else, he is afraid of things he doesn't understand.

The manufacturers of Celotex, by applying an old principle—insulation—to house construction and by using all the genius which modern advertising methods have to offer makers of a meritorious product, have

established a new industry and provided a market for most of the Louisiana sugar-cane bagasse, the crop by-product of cane-sugar production. The success of Celotex has stimulated active interest in the possible use of cornstalks, wheat straw and similar by-products of cereal growing, not only for the manufacture of wallboard, but for paper, cellulose pulp and chemicals. Capital has already been invested in the Corn Belt to manufacture cellulose pulp out of cornstalks. A factory at Tilton, Illinois, a suburb of Danville, is now in operation with a pilot mill, and large-scale production is expected to start during the summer. Iowa State College has planned thorough-going investigations on the utilization of farm wastes in coöperation with the National Bureau of Standards, and Prof. O. R. Sweeney, head of the Department of Chemical Engineering of the college, has caught the popular imagination with his descriptions of the possibilities of cornstalks for wallboard, pulp, paper, and in chemical manufacture.

The industrial value of these by-products of farming will be indicated largely by their content of cellulose, the principal constituent of the stalks of thick-stemmed, woody plants, which gives wood much of its structural strength and makes it valuable as a source of paper, rayon, etc. Cornstalks and straw will be used in industrial processes if their annual yield of cellulose compares favorably with that of trees, if the cost of collecting the raw material is not excessive and if the chemical, engineering and economic problems involved

in their manufacture are satisfactorily solved. They may also prove to have additional value by reason of the yield of by-products of a chemical nature which may develop in the course of manufacture.

In order to make an intelligent appraisal of the possibilities of farm-crop by-products as raw material for manufacturing, it is necessary to devote attention briefly to the consumption and production of forest products in the United States. There is no intention on the part of the author to attempt a dissertation on forestry, but, on the best information obtainable, he will present a layman's view of some of the more noteworthy facts pertaining to our forest industry. If farm wastes are to be used in the production of things which will probably come into competition with similar products derived from raw material produced by trees, we should have a fairly accurate picture of the productive possibilities of our forests.

The increase in the price of wood is in part responsible for the development of the use of lumber substitutes during the past 25 years. Still more important in their effect on the use of lumber have been the requirements of modern building construction for materials of greater strength and fire resistance than lumber.

Paper:

The story of paper is entirely different from that of lumber. No substitute for paper has yet been found. In 1899 the average price of pulp-wood f. o. b. mill was $4.95 per cord; in 1926 it was $14.96; an increase of

Photograph courtesy of U. S. Dept. of Commerce

ABANDONED WASTE BURNER OF THE GREAT SOUTHERN LUMBER CO., BOGALUSA, LA.

Profiting by the experience of the meat packers, the modern lumber company meets changing economic conditions by eliminating waste and manufacturing its by-products.

Photograph courtesy of U. S. Dept. of Commerce

FARMERS DELIVERING PULPWOOD TO HALIFAX PAPER CORPORATION, ROANOKE RAPIDS, N. C.

This company uses 25,000 cords of wood a year. Its manager "sold" the idea of producing pulpwood to neighboring farmers. Now the company has a continuous supply of pulpwood for its mill and farmers have profitable winter work and a steady market for their wood.

202 per cent, compared with 146 per cent in the case of lumber. While these are official figures and as such are not to be challenged by laymen, the fact should be noted that persons in the pulp and paper industry do not accept them entirely without question, particularly as to the latest figures available, namely those for 1926. Some pulp and paper authorities, who may perhaps be suspected of having an ax to grind, insist that as average figures the cost for the entire country in 1926 of $14.96 was too high, that if the pulp-wood prices had been considered on a regional basis a different story would have been told. However, when we get into regional statistics, particularly when we get the inside story of costs of pulp-wood in individual mill operations, we do indeed find a different story. The cost of pulp-wood in the spruce regions is far higher than the average for the country for all pulp-wood, and instances have been reported to the writer by manufacturers who have recently paid as much as $23 and even $26 per cord for spruce-wood f. o. b. mill. It is stated by the adherents of the idea that the official figures are too high, that such instances of excessive high prices of spruce-wood may be explained by the fact that this wood was needed for a special purpose. It does not appear to be gainsaid, however, that these high prices have been paid for spruce-wood, although the fact should not be taken as an indication of average spruce-wood prices. In some cases paper-mill operators have found themselves facing the alternatives of going far afield and incurring heavy freight charges for their spruce-wood supplies,

or closing up for good, because nearby supplies have been exhausted and no steps have been taken to replace them.

The increase in the price of paper-base stock has had no effect whatever on the consumption of paper in the United States. In 1899 we used 2,158,000 short tons of paper, in 1926 we used 11,807,000 tons, an increase of 447 per cent. In 1899 the per capita consumption of paper was 57 pounds; in 1926 it was 202 pounds.

Paper making has been profitable and overproduction has caused a recession in pulp-wood prices since 1921, but, so far as our national wood problem is concerned—the national cellulose problem, if we may use that term—paper and paper requirements affect it very little. Locally, as in New England and the Lake States, the problem of finding sufficient and suitable wood for paper is serious, but, taking the Nation as a whole, paper accounts for only 2.6 per cent of the annual forest drain. If we produced all the paper we need from our own forests, importing no pulp-wood, pulp, or paper, less than 6 per cent of the present annual forest drain would be required.

Spruce-wood is now the main source of newsprint. Taking the resin out of Southern pine, practically and economically, so that newsprint can be made out of it, is the most important chemical problem in Southern forestry, on which the Southern timber interests could well afford to spend large sums in fundamental research. The chemist who does that will transform the Southern timber industry as Charles H. Herty transformed the turpentine industry twenty-five years ago. When the

time comes that a satisfactory grade of newsprint can be made from Southern pine wood, we will hear little more about "the paper shortage," because a tree large enough to cut for pulp-wood can be grown in fifteen years in the South as against thirty to fifty years required for Northern spruce. The development of the use of hardwoods for newsprint will also help the paper situation.

To use the language of the woodsman, paper is "small stuff." Adjustments and improvements in manufacturing processes, in forest management, in mutual relationships between manufacturers in the United States and owners of timber lands in Canada, the use of new woods and new raw materials for paper-making, the manufacture of paper from wood now used for fuel, the use of second growth from cut-over lands, developments on the Pacific Coast and in Alaska—these factors will help materially if not decisively to keep America well supplied with paper.

Lumber:

Lumber prices advanced from an average of $11.13 f. o. b. mill per 1000 board feet in 1899 to $27.34 in 1926, an increase of 146 per cent.

The consumption of wood in the form of lumber is to-day practically what it was 25 years ago, which means, according to Dr. Wilson Compton, Secretary of the National Lumber Manufacturers' Association, that per capita consumption of lumber "has declined from 460 feet in 1900 to 326 feet twenty-five years later."

The building requirements of the United States have

been met to an increasing extent by the use of steel, concrete and other lumber substitutes.

In this period of 25 years, the prices of pig iron at Pittsburgh increased only 17 per cent, while the production of iron and steel plates increased 440 per cent and that of structural steel 470 per cent. Production of Portland cement increased 1754 per cent and that of face brick 472 per cent. Quantities of stone sold increased 47.5 per cent from 1920 to 1925, the amount of crushed stone sold having increased 87 per cent in these five years.

The future supply of saw timber presents many complicated questions. We are using up our forests at the rate of 25 billion cubic feet a year and replacing what we take off at the rate of only 6 billion cubic feet a year, according to official statistics. So we are cutting and destroying our forests at least four times as fast as we are replacing them. The Forest Service analyzes this annual drain of 25 billion cubic feet as follows:[1]

Used as fuel................	38.33	per	cent
Used as fencing, poles and piling	7.64	"	"
Used for building, etc. (lumber)	39.17	"	"
Used for paper manufacture..	2.36	"	"[2]
Used for cooperage, furniture and small manufacture	1.97	"	"
Used for chemical manufacture	.92	"	"
Destroyed by fire, insects and disease	9.61	"	"

[1] See Table 22, Statistical Bulletin 21, United States Department of Agriculture.

[2] 2.6 per cent according to the latest estimate.

Photograph courtesy of National Lumber Manufacturers' Association

REDWOOD SPROUTS IN CALIFORNIA

Natural redwood reproduction on the holdings of Union Lumber Company, Mendocine County, California. Redwood rarely propagates from seed. When a redwood tree is cut, large numbers of sprouts grow up around the stump from rhizomes, or underground root stocks. Each one of the bushes in this picture is a redwood clump. Protection from fire produced this result in four years.

Photograph courtesy of National Lumber Manufacturers' Association

REDWOOD SPROUTS AFTER FIFTY YEARS

An old redwood stump with its sprouts around it, now of marketable size, on the holdings of Union Lumber Company in California. Redwood produces more annual growth per acre than any other tree commonly found in our forests. A reason is seen in this and the following picture.

The largest single item in our annual drain of forest resources is thus seen to be the lumber that is used for various sorts of construction, which accounts for 39 per cent of the total.

The Forest Service estimates that 98 per cent of the rural buildings in the United States are made of wood, and that 90,000,000 of the people in this country live in frame dwellings, counting stucco and brick veneer as frame. The population of the United States increases approximately 1½ millions annually, which requires housing for 3,000,000 5-person families every ten years. If depreciation and obsolescence are allowed for, it is estimated that, in order to keep the American people adequately housed, 450,000 such houses or their equivalent must be provided annually. The increase in housing requirements has been reflected in the price of lumber, but not in the volume used.

Annual Growth from Trees:

Will the growth of wood from timber lands supply the lumber needed to erect the structures of the future where frame buildings are now the principal ones in use, or will lumber substitutes be used in small-house construction and farm buildings as they are now used in office buildings and apartment houses? The answer to these questions will in part depend on the annual growth which can be obtained from trees and the time required to grow it, compared with the amount of growth which can be obtained from annual plants.

The following figures on the yield of wood per acre per year have been furnished by the Forest Service:

Yield of Wood per Acre per Year

Quality of Site	*At 30 Years of Age* *Cu. ft.*[a]	*Tons*[b]	*At 60 Years of Age* *Cu. ft.*[a]	*Tons*[b]
	NORTHERN WHITE PINE (*Pinus strobus*)[1]			
Good	135	1.7	176	2.2
Average	108	1.3	142	1.8
Poor	82	1.0	109	1.4
	RED SPRUCE (*Picea rubra*)[10]			
Good	35	.5	122	1.7
Average	28	.4	102	1.4
Poor	22	.3	81	1.1
	LOBLOLLY PINE (*Pinus tæda*)[6]			
Good	177	3.4	154	2.9
Average	133	2.5	116	2.2
Poor	92	1.7	79	1.5
	LONGLEAF PINE (*Pinus palustris*)[6]			
Good	135	2.8	142	2.9
Average	82	1.7	86	1.8
Poor	33	.7	35	.7
	SLASH PINE (*Pinus carribæa*)[6]			
Good	160	3.8	122	2.9
Average	123	2.9	97	2.3
Poor	83	2.0	63	1.5
	SHORTLEAF PINE (*Pinus echinata*)[6]			
Good	132	2.5	137	2.6
Average	104	2.0	100	1.9
Poor	65	1.2	62	1.2
	REDWOOD (*Sequoia sempervirens*)[8]			
Good	340	5.1	337	5.0
Average	145	2.2	285	4.3
Poor	122	1.8	240	3.6
	DOUGLAS FIR (*Pseudotsuga taxifolia*)[7]			
Good	158	2.7	208	3.5
Average	137	2.3	181	3.1
Poor	109	1.8	144	2.4

	WESTERN WHITE PINE (*Pinus monticola*) [8]			
Good	52	.7	127	1.7
Average	41	.5	98	1.3
Poor	29	.4	70	.9
	JACK PINE (*Pinus banksiana*) [9]			
Good	98	1.5	80	1.2
Average	78	1.2	62	.9
Poor	55	.8	46	.7
	COTTONWOOD (*Populus deltoides*) [2]			
Good	—	—	—	—
Average	194	2.8	—	—
Poor	—	—	—	—
	TUPELO GUM (*Nyssa aquatica*) [3]			
Good	—	—	—	—
Average	74	1.3	—	—
Poor	—	—	—	—
	ASPEN (*Populus tremuloides aurea*) [4]			
Good	10	.1	50	.7
Average	—	—	35	.5
Poor	—	—	22	.3
	ASH (*Fraximus Americana*) [11]			
Good	130	2.6	120	2.4
Average	80	1.6	90	1.8
Poor	32	.6	58	1.2

(a) This volume includes the trunk or bole of the tree, not the limbs and stump.

(b) This weight is based on air dry moisture (12 to 15% moisture).

[1] White Pine Under Forest Management—U.S.D.A. Bulletin 13—Figures for N.H.

		Cu. Ft.		
Maximum average annual growth	:Site I	176.4	at	55 yrs.
	:Site II	141.8	at	55 yrs.
	:Site III	110.9	at	75 yrs.

[2] Cottonwood in the Mississippi Valley, U.S.D.A. Bulletin 24—Maximum average annual growth—average site—259 cu. ft. at 16 years.

[3] Preliminary Study of the Growth and Yield of Second-Growth Tupelo Gum in the Atchafalaya Basin of Southern Louisiana, by E. W. Hadley, in *Lumber Trade Journal*, November 16, 1926.

Table goes only to 50 years—at which age the average annual growth is given at 94.5 cu. ft. per year. (The growth rate is still increasing at this age.)

Footnotes continued on p. 90.

This table seems to be entirely clear, but a few words of explanation will obviate possible misunderstanding. Note that the volume in cubic feet does not include limbs or stump, and that the weight in tons is on an air-dry basis with 12 to 15 per cent moisture. Yields are averages per annum, from date of planting to 30 years in the first group of figures and to 60 years in the second. References to "site indexes" in the footnotes to this table indicate the height from the ground which a tree may be expected to reach in 50 years. It is to be regretted that the Forest Service, through no fault of its

[4] Aspen in the Central Rocky Mountain Region, U.S.D.A. 1291.

		Cu. Ft.			
Maximum average annual growth	:Site I	51	at	70	yrs.
	:Site II	41	at	80	yrs.
	:Site III	33	at	100	yrs.

[5] Volume and Yield Tables for Western White Pine, Mss. by I. T. Haig—1927.

		Cu. Ft.			
Maximum average annual growth	:Site I	154	at	100	yrs.
	:Site II	118	at	110	yrs.
	:Site III	84	at	110	yrs.

Site I is taken at site index of 80.
Site II is taken at site index of 60.
Site III is taken at site index of 40.

[6] Growth and Yield of Southern Pines, Mss. by R. D. Forbes—1927.

Site I
Loblolly —site Index 110 ft.
Longleaf —site Index 100 ft.
Slash —site Index 100 ft.
Shortleaf—site Index 90 ft.

Site II	*Site III*
Loblolly —site Index 92 ft.	Loblolly —site Index 70 ft.
Longleaf —site Index 74 ft.	Longleaf —site Index 50 ft.
Slash —site Index 81 ft.	Slash —site Index 60 ft.
Shortleaf—site Index 70 ft.	Shortleaf—site Index 50 ft.

[7] Article in *West Coast Lumberman*, May 1, 1926.

[8] Bulletin 361—University of California, 1923.

[9] Jack Pine in Lake States, Mss. by A. E. Wackerman—1926.

[10] Yields of Second Growth Spruce and Fir in Northeast, Mss. by W. H. Meyer—1927.

Site I is taken at site Index of 70.
Site II is taken at site Index of 60.
Site III is taken at site Index of 50.

[11] "The Ashes: Their Characteristics and Management", by W. D. Sterrett, Forest Service, U.S.D.A. Bulletin 299—1915.

own, was not able to find satisfactory figures on the annual growth of white spruce and hemlock. It may be said, however, that the yield of white spruce is probably about the same as that of red spruce and the growth of northern hemlock is about the same as that of northern white pine.

The most striking fact shown in the table is the rapid growth made by redwood and Douglas fir and by the southern pines when they are compared with northern conifers. If we take the age of 30 years as the period of growth for commercial trees, the southern pines more than hold their own with Douglas fir and redwood, particularly when grown on average and poor sites. Northern white pine and red spruce come into their own when allowed to stand for upwards of sixty years.

Shortleaf pine, the slowest growing of the southern pines, grows considerably faster in tonnage produced than northern white pine and makes five times as much growth in 30 years as northern red spruce, while slash pine and loblolly pine grow twice as fast as northern pine and six to seven times as fast as red spruce in 30 years. Slash pine, the best source of turpentine, makes less growth in cubic feet than loblolly pine, but excels loblolly pine in tonnage yield on account of its greater turpentine content.

If we rank the trees for which data appear in each category in the above table it appears that their productivity, considering both annual production in cubic feet and tons per acre to the age of 30 years, grades them as follows: redwood, slash pine, loblolly pine, Douglas fir, shortleaf pine, longleaf pine, northern

white pine (the latter two of equal value), ash, jack pine, western white pine, red spruce. At the age of 60 years the southern pines fall back somewhat, while northern white pine and red spruce come up.

Like southern pines, but in a smaller degree, northern white pine and Douglas fir have not yet been used in the cellulose industries and for paper making as spruce is used on account of the resin in the wood. Redwood has a drawback as a source of cellulose in its dye, but that may become an asset as a by-product. The cellulose of redwood, according to Hawley and Wise ("The Chemistry of Wood") is low in quantity but very high in quality (cellulose, 48.45 per cent, of which 78.81 per cent is Alpha cellulose).

As American forestry more nearly approaches the time when tree growth will be quite as important as tree cutting, the rapid growing trees will inevitably crowd the slow growing ones into the background, except as slow growing trees possess peculiar qualities not to be found in other species. For this reason, most emphasis has been placed in this discussion on tree growth up to thirty years. An industry which cannot foresee its harvest in less than sixty years stands a poor chance in fast-moving America. It is probably true, however, that more progress is being made in commercial forest reproduction in the United States than is generally known. Surely the efforts of the past thirty years to educate the public in general and timber owners in particular to an appreciation of the importance of rational forest management have not been entirely wasted.

Wood Waste:

The amount of material now wasted in cutting and processing timber in the United States must be reckoned with as a source of competition for cellulose from annuals or from trees themselves. It is a highly important, but apparently a very uncertain factor. Unfortunately, the data on it are incomplete and those on costs are unsatisfactory.

The statistics published annually by the United States Bureau of the Census in coöperation with the Forest Service estimate the cost of wood waste (mill waste) for the year 1926 at $8.52 per cord f. o. b. mill.

An analysis of this estimate made in the summer of 1927 for the Department of Agriculture, which the writer is permitted to publish, was as follows:

Region	*Cost per cord f. o. b. mill*
Atlantic Coast	$12.18
Southern Coast	5.45
Interior eastern	7.47
Pacific Coast	4.42

It seems certain that, in many cases, timber waste and even mill waste can be obtained for much less than these figures. One company in the South using its waste for fuel finds that it can change to coal at a cost that indicates a value of $3 per ton for the wood waste as fuel, and no expense of collection is involved except to change the direction of the waste conveyors. Other cases have come to the author's attention where Southern wood manufacturers find an average cost of about

$3 a ton for their raw material. Without being able to go deeply into the matter for lack of data, it would appear that the Government figures for costs per cord of mill waste are high, certainly in the South, even if we concede an air-dry weight for waste of 2 tons per cord. In many Southern mills, wood waste is sold at 50 cents to $2.50 a cord where a good fuel market is available.

The amount of mill waste is very large. One mill in the South reports a ten-hour test run as follows on 200,000 feet log scale:

Commercial lumber, 4″ and under 6′ and longer ...	56 per cent
Sawdust	20 per cent
Solid waste	24 per cent

About one-fourth of the solid waste was bark. Sawdust and bark were burned. The useable solid waste was manufactured into barrel staves, crating and the like, and the rest was run through a hog with the shavings and sold as fuel at 50 cents a ton.

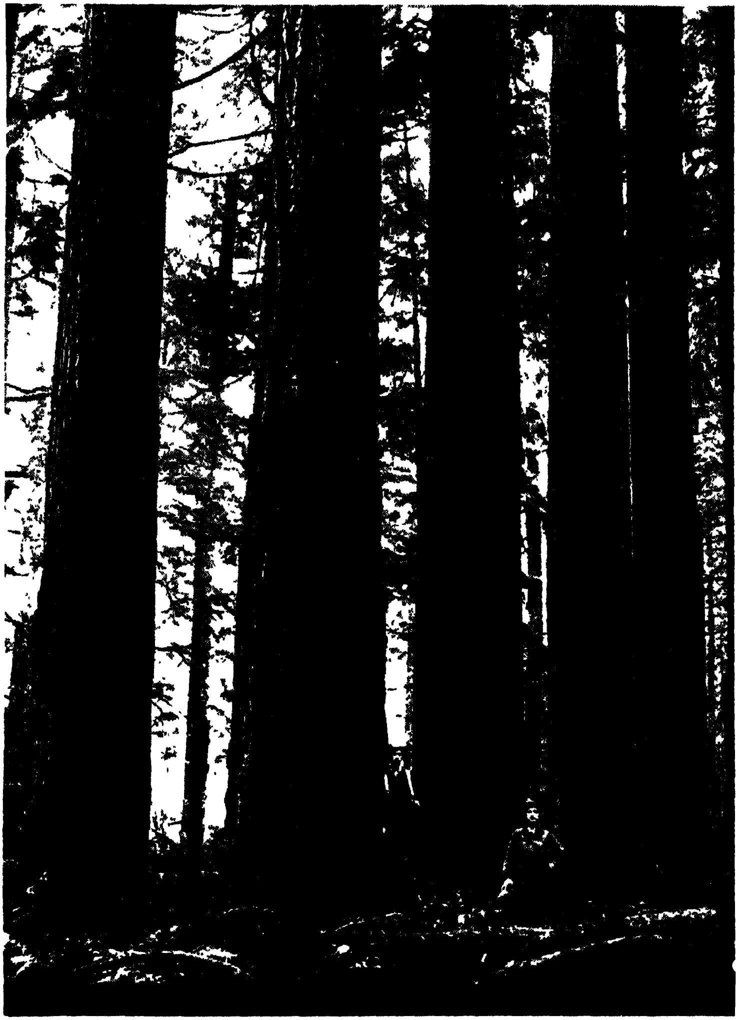
Progress in Commercial Forestry:

Timber owners who have been able to make headway in producing annual growth from their woodlands are in an enviable position, and they are already getting returns for their foresight. The so-called abandonment of farms to forests in New England and other parts of the East is still in progress and some sawmill and paper concerns are turning to production of growth on present lands for their supplies rather than extending

Photograph courtesy of U. S. Dept. of Commerce

A LITTLE ARMY OF MEN AND BOYS PLANTING PINE SEEDLINGS ON THE PROPERTY OF GREAT SOUTHERN LUMBER COMPANY, BOGALUSA, LA

This company believes strongly in artificial planting as a supplement to natural reseeding.



John D. Cress photograph courtesy of National Lumber Manufacturers' Association

VIRGIN DOUGLAS FIR IN A PACIFIC COAST FOREST

The lumber coming from the virgin timber of the Far West has had a demoralizing effect on the entire industry, leading to wasteful methods and retarding the development of systematic commercial timber production.

their reach for virgin supplies on new lands. Fire protection, good management and the planting of young trees are being resorted to where the owners have calculated that such a policy will be profitable and where they have the resources to carry it out. Dr. Compton states that ten years ago there were only three commercial forestry enterprises outside of New York and New England, whereas to-day more than one hundred substantial lumber properties are being managed with a view to continuous operation. A recent survey made by the United States Chamber of Commerce showed 174 owners of timber lands in the United States which are adopting or are planning to adopt such practices.

Selective logging has been found in most cases to yield more timber than clean cutting and the practice is attracting much attention in the Lake States. Protection against fire is bringing young trees on rapidly in the South and in certain sections on the Pacific Coast. Some sawmills are producing especially for the quality lumber market, cutting out knots, thus turning into No. 1 dimension stuff logs which could not have been so processed in the days of cheap lumber. Instead of leaving in the woods every part of felled trees that runs under 6 inches in diameter, some timber owners now require everything to be taken out that will measure 3 inches in diameter and over.

The integration of industries—the combination of other manufacturing processes with sawmill operations—is becoming more and more common. Timber owners are meeting the challenge of Celotex, one of the

most active competitors of Celotex being a lumber company which is making insulating board out of spruce-wood. Indeed it is said that this spruce-wood insulating board actually preceded Celotex on the market.

Lumber companies are becoming paper companies, because a log large enough for pulp-wood can be grown in half the time required to grow a saw log. Where these companies protect their woods against fire and systematically forest them, many of them have found that they have enough timber growing each year in their forests to keep their mills going indefinitely. One such company operating in the North informs the writer that it is going even further and is planting five trees for each one it cuts. It is said that this company expects to begin cutting in 1932 the trees which it planted many years ago in Northern New England. It is also known that paper companies whose mills are under operation in New York are going to Canada for their pulp-wood, leaving their Adirondack forests untouched. A lumber company operating in the South is cutting the tops of its saw logs into cord wood when they are felled and turning this cord wood into kraft paper in its own mills, thus conserving those parts of its forests which are the principal source of its pulp-wood.

It does not take a prophet to see that the lumber man of the future will be a manufacturer as well as a logger and sawmill operator.

It must be pointed out that, in proportion to the total number of sawmill operators in the country

(10,000 to 20,000) the number who are using methods to conserve annual forest growth is extremely small. The rapid cutting of virgin timber, to realize on investments made in the past and to meet tax bills, is still keeping the market supplied with first-class lumber at a cost which appears to be less than it takes to grow trees. At any rate, capital hesitates to put money into the long 30- to 60-year process required to bring trees to saw-log size when virgin trees still stand in the forest waiting for the lumber-jacks. The time factor has been the great obstacle to the reforestation of cut-over timber lands.

There seems to be little doubt that the United States will never go back to the extravagant use of wood which prevailed up to thirty years ago. This is the opportunity of the man who has visions of turning cornstalks and straw into industrial products.

CHAPTER V

CORN AS A SOURCE OF CELLULOSE—I

In the preceding chapter we examined the most recent available data on the annual growth in cubic feet and tons per acre of common forest trees, our chief source of cellulose at present. Reference was made in that chapter to the efforts now under way to utilize the potential sources of cellulose in annual farm crops and to the changing conditions in the timber industry to meet this and other forms of "The New Competition."

In this chapter we shall examine the data on yields of cellulosic material from annual crops which the author compiled during the course of his survey for the Secretary of Agriculture of research data pertaining to the industrial utilization of farm products.

With the courteous coöperation of the State Agricultural Experiment Stations in the Upper Mississippi Valley, comprising the principal corn and wheat growing sections, the author obtained data on the annual yield of grain and forage produced under controlled conditions in field-crop experiments conducted by those stations. Most of these data cover such a long period of time that fluctuations due to climate have been eliminated. Those in Illinois were obtained in thirty-one different localities throughout the State and rep-

resent the various soil types found in that Commonwealth. The data for each State will be found in the appendix at the end of this book where the reader who is interested will also find details for the various Illinois soil fields from the beginning.

For the benefit of readers who may not be familiar with agronomic terminology, let it be said that corn stover is the part of the corn plant remaining after the ears are husked out. It includes the stalks or stems, the leaves, the husks and the tassels. The ratios of stover to grain referred to in the following discussion were obtained simply by dividing the total weight of stover by the total weight of grain.

Considering records of corn stover yields, even from the state experiment stations, it must be remembered that stover and straw are at best cheap products and the further west we go the less value they have. Corn, for example, is usually grown for its grain yield and after it was learned that the best corn to put into the silo was the corn with most grain on it, little emphasis was placed on the total possible yield of gross tonnage by the entire plant.

The idea of growing corn and other cereals for heavy forage yields to produce a raw product for manufacturing as well as grain is new and the information available on this subject must be regarded as imperfect. Certain checks can be applied, however, which make it possible to determine with fair accuracy the amount of cellulosic material which may be grown from them. At the same time, it may be said that the data

which we have on forage yields of cereals is quite as accurate as that which we have for annual growth of trees.

Corn is a variable crop. Its yield is affected by weather conditions, by the fertility available, by the character and condition of the soil, by the variety grown and so on. Experiment station data for corn grown under different conditions of fertility supply, show that where the soil treatment given the crop is insufficient to produce maximum yields of corn, the yields in bushels per acre generally agree quite closely with the actual yields of grain per bushel for all farms in the respective states as reported in the United States Department of Agriculture Yearbooks. The yields of stover in such cases may therefore be taken as indicative of the average stover yields per acre in the states in question. Where soils received the best treatment, the experiment station data indicate what corn varieties now grown may be expected to yield in gross tonnage under the best farm practice.

Beginning with Ohio let us take the data for the states straight through the Corn Belt and study them with these two points in mind.

Ohio:

The soil at the Ohio Experiment Station is not particularly fertile and corn grown there requires heavy applications of barnyard manure for best results. The data cover 14 years, so that the weather influence is ironed out. The data follow:

Photograph courtesy of U. S. Dept. of Agriculture

CORN SEVENTEEN FEET HIGH IN NEBRASKA

When it pays to produce corn for gross tonnage of stover as well as grain, the yields in raw cellulosic material will probably greatly surpass production of annual growth from trees. The photographer who took this picture failed to identify it; so the variety is not known.

Photograph courtesy of U S Dept of Agriculture

A FIELD OF WOODBURN WHITE DENT CORN IN OHIO

On good soil in the Corn Belt an average yield of 2 to 2½ tons of corn stover may be expected from varieties of corn now commonly grown. This compares favorably with the annual growth of forest trees.

Ohio	*Average Production Per Acre* — *Grain* *Bus.*	*Grain* *Lbs.*	*Stover* *Lbs.*	*Ratio of Stover to Grain* *Per cent*
Fertilizer; no manure	47.46	2,658	2,059	76
Manure and phosphate	75.18	4,210	3,541	84

The average grain yield where the crop received no stable manure is considerably more than the average Ohio farm production of 39.2 bushels per acre from 1911-20 and 39 bushels from 1921-25, but it is probably no less than good farmers average throughout Ohio.

Kentucky:

In Kentucky the data not only show the value of limestone and phosphate, but they were obtained on several fields over the State, so that they are representative of the corn-growing sections. The data cover a period of fifteen years and are as follows:

Kentucky	*Average Production Per Acre* — *Grain* *Bus.*	*Grain* *Lbs.*	*Stover* *Lbs.*	*Ratio of Stover to Grain* *Per cent*
Manure	29.46	1,650	1,907	116
Manure, limestone and phosphate..	46.28	2,592	2,848	110

The average corn crop in Kentucky for the five years 1921-1925, was 26.7 bushels per acre and for the 10 years 1911-1920 it was 27.3 bushels. The yield of

the corn-experiment fields which received only manure is therefore quite close to the average on farms for the State as a whole.

Indiana:

In Indiana the data furnished are for the average yields of corn grown in rotation for eleven years at the State Agricultural Experiment Station as follows:

	Average Production Per Acre			*Ratio of Stover to Grain*
	Grain		*Stover*	
	Bus.	*Lbs.*	*Lbs.*	*Per cent*
Indiana	56.06	3,139	3,411	109

The average farm production in Indiana was 36.1 bushels per acre for the five years 1921-1925 and 36.4 bushels per acre for the ten years 1911-1920. The yields reported in these data from the Stations are therefore much better than the average farm production of the State as a whole.

Illinois:

The data from the Illinois soil fields are so comprehensive that they repay close study and somewhat detailed analysis. The time covered has been long enough to eliminate variations in production due to the vagaries of the weather, and the data come from thirty-one fields located at different points throughout the State which gives a good cross-section of Illinois corn-production.

Note the following:

Illinois	*Average Production Per Acre* *Grain* *Bus.*	*Lbs.*	*Stover* *Lbs.*	*Ratio of Stover to Grain* *Per cent*
No soil treatment	34.53	1,934	2,757	143
Manure	44.19	2,475	3,424	138
Manure and lime.	49.95	2,797	3,875	139

The average corn crop in Illinois for the five years 1921-1925 was 36.4 bushels per acre, and for the ten years 1911-1920 it was 33.7 bushels. Therefore the yields from the no-soil-treatment plots are almost exactly in agreement with those of average corn production on the farms of the State. The corn in these tests was grown in rotation and the cornstalks produced were returned to the soil, but straw from small grain was not.

Let us analyze the Illinois data further to get a closer line on factors of variability. If we take the data found in the tables of the appendix for the five fields (counties in the tables) which produced the highest yield of grain with no soil treatment and get the weighted average for them; then take the five fields with highest yields of stover and average them; then take the five fields with the lowest yields of grain and the five fields with the lowest yields of stover; and make similar selections of corresponding fields which received manure and lime, calculating the weighted averages in the same way in each case, we get these results.

Illinois Soil Fields—Comparative Data for Selected Fields

	Average Production per Acre			*Ratio of stover to grain*
	Grain		*Stover*	
No soil treatment	*Bus.*	*Lbs.*	*Lbs.*	*Per cent*
Five highest producing fields				
On basis of grain yields...	58.14	3256	4059	125
On basis of stover yields...	53.76	3010	4296	143
Five lowest producing fields				
On basis of grain yields...	12.82	718	1478	206
On basis of stover yields...	13.72	769	1394	181[1]
Manure and lime				
Five highest producing fields				
On basis of grain yields...	68.99	3864	4654	120
On basis of stover yields...	66.02	3697	4966	134
Five lowest producing fields				
On basis of grain yields...	30.38	1701	2944	173
On basis of stover yields...	33.42	1872	2782	149[1]

1 Note that the fields in these groups were those with the lowest production of stover. This accounts for the apparent contradiction when these stover-grain ratios are compared with those of the lowest grain-producing groups.

This comparison shows clearly the effect of soil and fertility on corn production, and strikingly illustrates the possibilities in stover production. We have seen that the average production of corn in bushels of grain per acre obtained on the Illinois soil fields without soil treatment is almost exactly the average annual yield of the crop on Illinois farms for the past fifteen years, an average yield per acre of 34.53 bushels on the experimental fields without soil treatment, 36.4 bushels for the State as a whole from 1921-1925 and 33.7 bushels for the ten years from 1911-1920. We are thus justified in taking the stover yields in the experimental soil fields without soil treatment as indicative of stover production on farms and estimating

an average annual production of 2750 pounds of stover per acre on Illinois farms.

We can go still further and state, on the authority of the results obtained in these Illinois experiments as shown in the preceding comparison that, on the best Illinois corn lands, an average annual yield of 2 tons of corn stover may be expected without soil treatment and that where these good corn lands are manured and limed, the average annual stover crop will approach 2½ tons per acre.

It is apparent that an increase in grain yield in the corn plant is usually accompanied by a decrease in the relative amount of stover produced as we see from the following recapitulation:

STOVER-GRAIN RATIOS—SELECTED ILLINOIS SOIL FIELDS

	On the basis of grain yields		*On the basis of stover yields*	
	No soil treatment	*Manure and lime*	*No soil treatment*	*Manure and lime*
Best soils........	125	120	143	134
Poorest soils.....	206	173	181	149

The same fact appears in the summary of the Illinois data on page 103 and is clearly indicated in some of the details of the tables in the appendix. Obviously, when the corn plant has to exist on infertile, poorly nourished soils, mere existence is alone a struggle and is more important than seed production. When it is fed, corn does its best to produce grain and produces grain best under those conditions.

Indications that corn has been selected for a maximum of grain production with as little stover as possible are apparent in the Illinois figures. This is shown usually by a lower stover-grain ratio where heavy grain crops are recorded, although the actual production of stover may have increased, but in smaller proportion to the increase in grain production. Further discussion of the relation between variety grown and stover produced will appear later.

Missouri:

In Missouri the corn grown continuously without soil treatment produced less grain than the average in the State for the later years covered by the test, while plots grown continuously with manure or in rotation with or without manure produced considerably more than the State average as follows:

	Average Production Per Acre			*Ratio of Stover to Grain*
	Grain		*Stover*	
Missouri	*Bus.*	*Lbs.*	*Lbs.*	*Per cent*
Corn grown continuously without manure or fertilizer ...	20.85	1,168	2,052	176
Corn grown continuously with manure or fertilizer	34.86	1,952	2,889	149
Corn grown in rotation without manure or fertilizer	36.65	2,052	2,461	120
Corn grown in rotation with manure or fertilizer	44.41	2,487	3,084	124

The period covered by these data are for the years 1889-1918. The average yield of corn on farms in Missouri for the ten years 1911-1920 was twenty-six bushels per acre.

Iowa:

In Iowa the data presented in Table V (Appendix) exceed the average State production as is shown below.

	Average Production Per Acre			*Ratio of Stover to Grain*
	Grain		*Stover*	
Iowa	*Bus.*	*Lbs.*	*Lbs.*	*Per cent*
No treatment:				
1st year after clover sod	57.3	3,209	2,140	67
2nd year after clover sod	49.3	2,761	1,780	64
Manure, 8 tons per acre:				
1st year after clover sod	72.5	4,060	2,940	72
2nd year after clover sod	64.5	3,612	2,360	65

These data were for the years 1921-1925 when the average corn crop on farms in Iowa was 39.9 bushels per acre.

Other Corn Belt States:

The Kansas data for corn grown continuously on the same land, and the data from Nebraska are quite

closely in accord with farm corn production in those States. The Kansas data cover the years 1911-1926 and those from Nebraska 1918-1927. Corn yields on farms in Kansas averaged 20.3 bushels per acre in the five years from 1921-1925 and in Nebraska 26.8 bushels. Experimental data from Kansas, Nebraska and South Dakota are as follows:

	Average Production Per Acre			*Ratio of Stover to Grain*
	Grain		*Stover*	
Kansas	*Bus.*	*Lbs.*	*Lbs.*	*Per cent*
Grown continuously on same land for 16 years	19.03	1,066	2,014	189
Grown in rotation for 16 yrs.	26.59	1,489	2,712	182
Nebraska	28.51	1,597	2,634	165
South Dakota ...	30.35	1,700	1,855	109

The five-year average of corn production on farms in South Dakota was 26.8 bushels. A yield of 1 ton to 1½ tons of stover may therefore be expected on most farms in the three Corn Belt States west of the Missouri River.

Results of the Pennsylvania Tests:

The second oldest crop-growing investigations in the United States are those at the Pennsylvania State College which have been going continuously since the early 80's. Results are available for forty years' work

and the average of corn production per acre of all plots in these experiments is shown below:

Pennsylvania	*Average Production Per Acre*			*Ratio of Stover to Grain*
	Grain		*Stover*	
	Bus.	*Lbs.*	*Lbs.*	*Per cent*
All corn plots, average per acre..	46.1	2,582	2,345	91

The average annual yield of corn per acre on Pennsylvania farms for the ten years, 1911-1920, was 41.7 bushels, which is only slightly below the average yield per acre for forty years in the Pennsylvania State College experiments. Pennsylvania farmers already make quite a complete utilization of their corn stover and depend upon it to carry their cattle through the winter. Farmers are not likely to be interested in manufacturing cornstalks in that State, but the figures on yields at the college are too valuable to be omitted from this book.

Variety Tests:

Indications that the variety of corn grown has an effect on the amount of stover produced were referred to in discussing the Illinois data above.

Corn varieties with short stalks are commonly preferred to those with tall stalks. If the corn a farmer already grows produces more stover than he can dispose of, he gains something if he can still further increase the grain produced at the expense of the stalk.

So he selects his seed corn with a maximum grain production and a minimum stover yield in mind. This might make a difference in stover yields of the same variety grown in different localities. Another objection to excessive stalk growth has been the difficulty of harvesting grain from the tall varieties. Strains of corn are known, the stalks of which are so tall that the ears are 8 or 9 feet from the ground, practically impossible to harvest by hand. A market for stover to be used in manufacturing will provide an object in the growth of large stalks producing heavy yields of stover, especially when this is accomplished without decreasing grain production per acre. The use of machines for harvesting instead of hand labor should remove the second objection

Variety tests at the Ohio, Missouri, Tennessee and Illinois Agricultural Experiment Stations are inserted below. The Ohio data are taken from "Field work of the Ohio Agricultural Experiment Station, Wooster, Ohio, 1926"; and are averages of six years' tests with the varieties named. The Missouri data are from Bulletin 181 of that station and are averages of 6 years from 1908 to 1915, the year 1909 being omitted. The Tennessee data are taken from Bulletin 126 of The Tennessee Agricultural Experiment Station. In these three cases varieties are arranged in order of yields of stover. The source of the Illinois data is explained in the text, and the style of presentation follows that of the Illinois Station.

OHIO—CORN VARIETY TESTS

Variety	*Source of Seed*	*Average Production per Acre* Grain *Bus.*	Grain *Lbs.*	Stover *Lbs.*	*Ratio of Stover to Grain Per Cent*
Reid Yellow Dent	Fayette and Madison Counties..	57.58	3,224	4,687	145
Cook, No. 75	Hardin County	65.20	3,651	3,897	107
Darke County Mammoth	Darke County	61.49	3,443	3,731	108
Leaming	Lake County	65.56	3,671	3,583	98
Woodburn Yellow Dent	Champaign County	66.14	3,704	3,523	95
Leaming	Clinton County	63.21	3,540	3,438	97
Pride of the North	Nebraska [1]	56.78	3,180	3,425	108
Medina Pride	Medina County	67.55	3,783	3,348	89
White Cap	Wayne County	66.04	3,698	3,230	87
Clarage (Wooster)	Wayne County	65.65	3,676	3,214	87
Ohio 84 (Wooster)	Wayne County	65.59	3,673	3,120	85
Silver King	Portage County [1]	58.50	3,276	2,965	91
Longfellow Flint	Various Sources	50.05	2,803	2,803	100
Golden Glow	Wisconsin [1]	57.55	3,223	2,740	85
Minnesota No. 13	Minnesota	55.32	3,098	2,600	84

1 Seed occasionally obtained from other sources.

MISSOURI—CORN VARIETY TESTS

Variety—	*Average Production per Acre* Grain *Bus.*	Grain *Lbs.*	*Stover Lbs.*	*Ratio of Stover to Grain Per cent*
Commercial White	56.70	3,175	4,826	152
St. Charles White	51.30	2,873	3,856	134
St. Charles Yellow	46.80	2,621	3,824	146
Cartner	47.10	2,638	3,701	140
Boone County White	48.00	2,688	3,424	127
Johnson County White	46.30	2,593	2,954	114
Leaming	44.50	2,492	2,863	115
Reid Yellow Dent	47.70	2,671	2,502	94
Hogue Yellow Dent	46.80	2,621	2,456	94
Silvermine	40.50	2,268	2,212	98

TENNESSEE—CORN VARIETY TESTS

Experience and observation and agronomic experiments indicate that when corn is grown on good land south of the Corn Belt still higher yields of stover may be expected. In this section, the taller, later maturing white varieties are usually grown.

Mooers gives these average results of eleven years' yield of white varieties on Tennessee River bottom land near Knoxville. Yields were calculated on an air-dry basis.

Variety	*Yield per Acre* *Grain Bus.*	*Stover Tons*
Albermarle Prolific	69.9	2.53
Hickory King	65.3	2.17
Cocke Prolific	67.2	2.72

Yields of white varieties which are popular in Tennessee compared with northern varieties as follows, being averages of seven years' production at the Tennessee Agricultural Experiment Station at Knoxville:

	Yield per Acre	
	Grain	*Stover*
Variety	*Bus.*	*Tons*
Albemarle Prolific	70.5	2.55
Hickory King	67.1	2.14
Iowa Silvermine	52.7	1.35
Leaming	58.4	1.47

ILLINOIS—CORN VARIETY TESTS

Through the courtesy of Prof. W. L. Burlison, the author is privileged to publish the following data on stover yields from different varieties of corn from the records of the Urbana Soil Field of the Illinois Agricultural Experiment Station. The stover yield of Reid Yellow Dent, taken as standard, is compared with those of other varieties given.

The first column of the table shows the names of varieties grown; the second gives the number of years that each variety was grown; the third shows the average yield of stover for each variety for these years; the fourth column shows the average yield of Reid Yellow Dent for the same years; and the last column shows, for each variety in the first column, the proportion of the average weight of stover to the weight of the entire crop of grain and stover combined. The form in which the ratio data are presented is somewhat different from that found elsewhere in these pages. This information was received after the manuscript of "Farm Products in Industry" went to press,

ILLINOIS—CORN VARIETY TESTS

Variety	*Years grown Number*	*Stover per acre Tons*	*Standard —Reid Yellow Dent Stover per acre Tons*	*Ratio of stover to total crop* [1] *Per cent*
Boone County White	26 [2]	1.38	2.24	42.1
Champion White Pearl	23 [2]	2.65	2.40	60.0
Conner Prolific	4	3.97	2.56	68.5
De Kalb County Yellow Dent	3	1.33	2.47	45.2
Democrat	4	3.04	2.45	59.3
Drouth Proof	6	1.93	2.46	49.2
Funk—176A (Utility)	3	2.40	2.42	55.0
Funk—90 Day	15 [2]	1.89	2.32	50.6
Golden King	11	2.02	2.44	49.4
Hecker Red	6 [2]	1.68	2.42	51.8
Illinois High Ear	16 [2]	2.54	2.32	64.5
Illinois Low Ear	16 [2]	1.85	2.32	52.8
Illinois High Oil	16 [2]	1.59	2.10	51.8
Illinois Low Oil	16 [2]	2.01	2.10	57.2
Illinois High Protein	16 [2]	2.10	2.10	61.3
Illinois Low Protein	16 [2]	1.54	2.10	47.9
Illinois High Yield	7	2.54	2.48	52.5
Illinois Low Yield	4	2.34	2.45	55.2
Illinois Non-Pedigree	4	2.83	2.48	58.0
Illinois Two-Ear	8	2.56	2.46	52.5
Lancaster Sure Crop	4	2.16	2.52	51.2
Leaming	23 [2]	2.14	2.20	53.6
Perrine White Pearl	3	2.85	2.39	63.7
Reid Yellow Dent	26 [2]	2.24	2.24	53.4
St. Charles White	7	3.14	2.49	64.0
Silvermine	26 [2]	2.14	2.24	53.6
Strout Red	9	1.80	2.35	48.5
Sutton Favorite	4	2.77	2.31	59.2
U. S. Selection No. 77	3	3.29	2.51	63.3
Western Plowman	10	2.07	2.69	51.8
White Cap Yellow Dent	6	1.87	2.52	48.4
Will County Favorite	9 [2]	1.96	1.95	51.2
Wisconsin No. 7	6 [2]	2.02	2.56	54.6
Wyatt Boone County White	3	3.36	2.51	67.3

1 Average yield of stover in pounds divided by average yield of corn and stover combined equals percentage of stover of total production.
2 No stover record for the years 1907, 1910 and 1911.

and there was not sufficient time to convert the figures to uniformity with those in other tables. A little care on the reader's part will show that the same meaning is in that last column, although the style presentation is different.

It is interesting to note that Boone County White at the Illinois Station has produced more grain than stover. Most of the white varieties are heavier producers of stover than of grain, and they are usually heavier stover producers than the yellow varieties. Note other white varieties in the above, such as Champion White Pearl, St. Charles White and Wyatt Boone County White, and compare white variety yields at Ohio, Missouri and Tennessee. Variety differences in different states should also be noted. The same variety may show not only a different acre yield, but a different stover-grain ratio in one state as compared with another. Compare, for instance, the yields of Boone County White and Reid Yellow Dent in the Missouri data. Note also that Reid Yellow Dent was the highest producer of stover in the Ohio tests, with the highest stover-grain ratio. The author simply calls attention to these facts without attempting to explain them.

These Illinois variety data show many other interesting things. Reid Yellow Dent, which Prof. Burlison takes as standard, has produced an average yield on the Urbana Soil Field during 26 years of 2.24 tons of field-dry stover per acre. This variety has been grown with grain as the main object, and it is not surprising that other varieties for which yields have been obtained

at the Illinois Station show much larger production of stover. Note Conner Prolific, with an average of 3.97 tons of stover for 4 years, which was 68.5 per cent of the whole crop; Democrat, with an average of 3.04 tons of stover for 4 years, which was 59.3 per cent of the total; St. Charles White, with 3.14 tons of stover annually for 7 years, which was 64 per cent of the total; U. S. Selection No. 77, grown 3 years with an average stover production of 3.29 tons per acre, which was 63.3 per cent of the total; and Wyatt Boone County White with an average stover production of 3.36 tons per acre for 3 years, which was 67.3 per cent of the total crop. Assuming that 1/3 of this stover was water, these yields indicate a dry-matter yield of more than 2 tons per acre for these varieties. Deducting 50 per cent for the weight of leaves and husks, there is left a yield of more than 1 ton per acre in bone-dry material in the cornstalks alone.

Details of these Illinois variety yields, with analyses will be found in Tables XVIII and XIX of the Appendix.

As the author has already pointed out, the tendency in corn growing during the past thirty years in the United States has been strongly towards maximum grain production. Varieties of corn with heavy tall stalks can and have been produced, some of them with ears so high on the stalks that it is impossible for a man to reach them from the ground. As the grain is the most valuable portion of the corn plant, a minimum production of stover is desired as far as that is consistent with maximum grain production. Excessively

tall stalks are objectionable because of the difficulty of harvesting, and are entirely out of the question where hand picking is used.

If and when the manufacture of cornstalks into cellulose pulp becomes general, both objections will have little weight, because corn stover will then have an established value and harvesting with machinery will make it immaterial whether the ears are 4 feet or 10 feet from the ground.

A point which agronomists should settle by careful experimentation as their contribution to the research on this subject is the proper balance between grain production and stover production. Grain will always be the most important factor, no doubt, but the farmer who has a good market for his cornstalks will want to produce as heavy tonnage of stover as possible. How far can he go in this direction without reducing his grain yields? What effect will a heavy tonnage of stover have on the quality of grain produced? No answers can be given to these questions now.

However, by the end of 1928, Mr. Harvey J. Sconce, famous Illinois corn breeder and farmer, who is now manager of raw material production for Cornstalk Products Company, will have a mass of practical information on this subject which will be extremely valuable. On behalf of his company, he has arranged for what he claims with undoubted truth to be the most extensive corn-growing experiment ever planned. He has planted 980 acres of good corn land in Vermilion County, Ill., to some 80 varieties of corn from which he is collecting accurate data on operation and

production costs. This corn is grown on different types of soil with different methods of fertilization and different kinds of fertilizer. Different thicknesses of planting are used, most of it being planted in the usual manner, 3 and 4 kernels to the hill. In some cases there are 1, 2, 3, 4, 5 and 6 kernels to the hill. In addition to sowing corn with the planter and check-rower, corn was drilled and broadcast. The drills were 20, 28 and 40 inches apart. Where the drills were 40 inches apart kernels were sown 12, 8, 6 and 4 inches apart in the rows. In the drills which were 28 and 20 inches apart the kernels were all sown 8 inches apart in the rows. When this experimental crop is harvested, Sconce will know more about the productive possibilities of the corn plant than any man living. Let us hope that he will promptly make his information public.

If the reader will compare the data on corn-stover yields in this chapter with those on annual yields per acre of wood from common forest trees, he will get a wholesome respect for the possibilities of the giant cereal as a producer of raw cellulosic material. Yields of both are on an "air-dry" basis, which is estimated to indicate from 12 to 15 per cent moisture in the case of wood and considerably more in corn stover.

It is evident from the information presented in this chapter that, on good Illinois corn lands, an average annual yield of two tons of corn stover per acre may be expected without soil treatment and that, where these good corn lands are manured and limed, the average annual stover crop will approach two and one-half tons per acre. As a matter of fact, some of the

Illinois soil fields have averaged more than two and one-half tons of stover per acre. In Putnam County, where the soil does not respond to treatment, corn with no soil treatment averaged 5,534 pounds of stover per acre from 1911 to 1926. Of thirty Illinois soil fields receiving manure and lime, thirteen averaged over two tons of stover per acre, and two of them, one in Bureau County with eighteen plantings from 1913 to 1926, and the other at the Experiment Station at Urbana in Champaign County with sixteen plantings from 1911 to 1926, averaged over two and one-half tons of stover per acre.

While equally detailed experimental data are not at hand for the great corn State of Iowa, there is no doubt that yields of stover in the Hawkeye State will compare favorably with those in Illinois, if they do not surpass them.

In the next chapter we shall see what the corn plant actually produces in "bone-dry" cellulosic material in the stover, and we shall also get a glimpse of what may be done with corn in this respect when it pays the farmer to grow it for that purpose.

CHAPTER VI

CORN AS A SOURCE OF CELLULOSE—II

THE water which is normally present in the raw material used by the manufacturer of pulp and paper is of no value to him, and the yield of manufactured product in proportion to the total air-dry weight of raw material purchased has a distinct bearing on his ultimate profits. Therefore it is necessary for him to base his plant accounting on the water-free or "bone-dry" substance in the raw material.

Corn stover readily absorbs moisture from the air. It may contain less than ten per cent of moisture and it may contain as much as fifty per cent or even more. The manufacturer of this material must know approximately how much moisture he is likely to find on the average in the cornstalks which he purchases. Still more important is it to know how much actual dry substance may be expected per acre per year in the territory from which he draws his supplies of raw material. It is possible to refer the reader to experiment station results conducted with the greatest care and thoroughness, in which will be found accurate information on this subject.

Corn Stover Yields in "Bone-dry" Material:

The moisture content of corn stover at the time of weighing probably has a great deal to do with varia-

tions in stover yields as reported by different experiment stations. Usually experimental data at any one state agricultural experiment station are collected in a uniform manner from year to year. For corn stover these weights are determined on the "field cured" condition of the corn matured in the shock or standing in the field. The results at any one experiment station may therefore be compared year by year, although they may not be compared with those from another station where some difference in time of harvesting or method of curing the stover may be followed. For this reason the reader should consider the data from the various state agricultural experiment stations separately and not attempt to average them.

Accurate determinations of the yield of stover should show the yields in bone-dry moisture-free substance—"dry matter" as it is usually reported in experiment station bulletins.

Available data of comparatively recent origin are presented below.

DRY MATTER IN CORN STOVER PER ACRE

State	*Variety*	*Pounds*
Indiana	Riley's Favorite:	
	Matured in field	2,654
	Cut Oct 8; matured in shock	3,989
	Cut October 8	4,226
Kansas	Pride of Saline:	
	Total production, 10,178; in grain and cob, 40.3% in remainder	4,102
North Dakota		4,830

These yields were obtained in the course of chemical studies of the corn plant and were calculated by taking average samples of the crop grown and calculating the total dry-matter production per acre on the basis of the dry content in these samples determined in the laboratory, in much the same way that a timber cruiser calculates the total yield in a tract of timber by counting and measuring the trees on representative measured areas.

In Indiana, the authors of the bulletin reporting the results suggest that they are twice the Corn Belt average. On this basis, a dry-weight yield on farms of 1,300 pounds for stover cured on the stalk may be expected and 1,900 pounds where it is cured in the shock; a farm yield of 2,000 pounds would thus be indicated in Kansas, and somewhat more in North Dakota.

The data from Indiana by Jones and Huston are especially important. The first samples were taken from corn cut on October 8. Some of the corn was shocked on that date and the remainder stood in the field to mature. The shocked corn was sampled on November 12, and a sample was taken on that date from the standing corn. The loss in weight of stover in the shock was 5.6 per cent, while the corn standing in the field lost one-third of its dry weight as compared with the corn in the shock. This loss was due to leaching and beating off of the leaves during storms. It would indicate that the best practice in growing corn for stover production will be to cut and shock it, doing the husking and baling the stover whenever weather is

favorable. To save a loss in weight of stover of more than 1,000 pounds of dry matter per acre should go far to compensate for the added cost of shocking.

Proportionate Weight in Different Parts of the Corn Plant:

Some chemists question whether cornstalks can be satisfactorily manufactured by a chemical process if the leaves and husks remain on the stalks, because these parts may become so finely comminuted that they are washed out by the chemicals and lost. The leaves and husks have feed value and are worth reclaiming for that purpose. It would not be at all difficult to devise an attachment for a husker-shredder that would strip the leaves and husks from the stalks before they reach the shredder rolls and blow this material out of one side of the machine where it could be baled and stored until fed. The Pennsylvania data on page 127 give information on the proportion of the corn plant in various parts. Data reported by Latshaw and Miller of the Kansas Experiment Station, and by Smith in Michigan agree closely and are as follows:

Per Cent of Dry Weight of Corn Plant

	Kansas	*Michigan*
Leaves	30	22
Stem	26	32
Cob	10	46
Grain	34	

In Kansas 44 per cent of the entire dry weight of the plant was in the ears, and in Michigan 46. If we

take these proportions as representative of corn as now grown they roughly show a dry matter yield of 45 to 50 per cent in the ears, 20 to 25 per cent in the leaves and husks and 20 to 25 per cent in the stalks. The total yield of dry matter per acre (ears, stalks and all), in the Kansas experiments was calculated at 10,178 pounds per acre, and in the Michigan tests 8,020 pounds.

Unpublished data by Ericson presented in a bachelor's thesis at Iowa State College indicate that in the corn plant from which the ears have been removed, the parts are distributed as follows:

Stalks	43	per	cent
Tassel	2	"	"
Leaves	36	"	"
Husks	19	"	"
	100	"	"

These studies show that approximately one-half of the weight of corn stover is in the leaves and husks. It is a cardinal principle in the manufacture of pulp and paper that no material should be used which is likely to have value as feed for animals. If we accept this rule and eliminate the husks and leaves of cornstalks, we still have the stalks themselves to be disposed of— a troublesome nuisance around the barnyard, of questionable value as feed or fertilizer, a possible carrier of disease and insect pests, but potentially valuable to the manufacturer. On the best Illinois corn lands

under good treatment (and probably in Iowa also) this raw manufacturing material amounts to at least 1 or 1¼ tons per acre per year, and with it goes an equal amount of fairly good feed not now utilized to the best advantage.

How Much Dry Weight Can the Corn Plant Produce Annually?

The subject of growing corn for maximum gross tonnage takes us back many years to the time when it was thought that the best corn for the silo was that with the greatest weight per acre, regardless of the amount of grain produced. These early experiments were conducted by men whose scientific standing was high and whose methods are still models of thoroughness and accuracy. In several of the reports of these experiments we find indications of what the corn plant may produce in gross tonnage when it is grown for that purpose.

Variety tests by Caldwell at the Pennsylvania Agricultural Experiment Station showed the following yields of dry matter in stover per acre:

Variety	*Dry matter in Stover per acre*
Flints—	*Pounds*
Angel of Midnight	1,629
Longfellow	1,826
Pipe Stem or Top Over	3,501
Self-Husking	1,301

Variety	*Dry matter in Stover per acre*
Dents—	*Pounds*
Champion White Pearl	3,832
Cleaver	3,527
Golden Beauty	6,035
Golden Dent	5,551
Hickory King	6,359
Leaming	4,121
Piasa Queen	4,748
Queen of the North	2,369
Queen of the Prairie	4,227
Wisconsin Earliest White Dent	2,595

Many of the dent corn varieties in these tests were not adapted to the altitude of 1200 feet at State College and did not mature grain. An interesting feature of these experiments is that Caldwell worked out the relative proportions of the plant and calculated the proportion of ears to stover, ears being 1, as we see in the table on page 127.

Thickness of Planting:

The conventional method of planting corn in the Corn Belt with a check-rower and hills 42 inches to 44 inches apart has been adopted on account of its convenience and labor-saving possibilities. It is clear, however, that this method of planting does not produce the optimum amounts possible of either stover or grain. C. D. Smith at the Michigan Agricultural Experiment Station found the following results, the weights being

Pennsylvania—Proportion of Parts

Variety	Ears: Corn	Ears: Cob	Stover: Leaves and husks	Stover: Butts	Stover: Tops	Total	Proportion of ears to stover
			100 Lbs. of Dry Matter is Distributed				
Flints—							
Angel of Midnight	52	9	29	7	3	100	1: .64
Longfellow	55	9	26	8	2	100	1: .56
Pipe Stem or Top Over	33	7	48	11	1	100	1:1.51
Self-Husking	57	10	23	7	3	100	1: .48
Dents—							
Champion White Pearl	42	10	27	18	3	100	1: .91
Cleaver	44	10	28	14	4	100	1: .83
Golden Beauty	32	9	38	15	5	100	1:1.43
Golden Dent	30	8	33	22	7	100	1:1.62
Hickory King	30	5	38	20	7	100	1:1.83
Leaming	40	10	29	15	6	100	1:1.72
Piasa Queen	34	9	32	18	7	100	1:1.77
Queen of the North	50	8	28	10	4	100	1:1.49
Queen of the Prairie	43	10	27	14	6	100	1:1.73
Wisconsin Earliest White Dent	51	12	25	8	4	100	1:1.48

given in pounds of dry matter per acre for the entire plant:

Crop of 1896	*Dry matter Pounds*
Plot 1—Drilled in rows 7 inches apart......	9,412
Plot 2—Drilled in rows 14 inches apart......	5,483
Plot 3—Drilled in rows 28 inches apart......	7,500
Plot 4—Rows 3 feet 9 inches apart, hills 1 foot 10 inches in the row, 4 kernels to the hill	5,815
Plot 5—Rows 3½ feet each way, 4 kernels to the hill	4,790
Silage corn	8,656
Sorghum	7,700
Crop of 1897	
Plot 1—Drilled in rows 7 inches apart......	5,940
Plot 2—Drilled in rows 14 inches apart, kernels about 3 inches apart in the row....	7,454
Plot 3—In rows 28 inches apart.............	6,295
Plot 4—In rows 42 inches apart.............	6,970
Plot 6—Not stated	6,426

This information, of course, sheds no light on the amount of corn stover which may be produced by increasing the thickness of planting. However, we find abundant information on this point at the Illinois Agricultural Experiment Station. Forty years ago Morrow and Hunt studied the effects of different thicknesses of planting for three years, the results being published in Bulletin 13 of that station.

Burr's White corn was planted in rows 3 feet 8 inches apart, kernels being planted at various distances in the row, the thickest planting being 3 inches apart.

Results are shown for kernels per acre in the average for the three years. Corn was cured in the shock and stover weighed direct from the field. The ratio between stover and grain was also calculated.

THICKNESS OF PLANTING—ILLINOIS
Average of 3 years.

Kernels per Acre	Stalks Harvested per Acre	Yield per Acre: Shelled Corn Bus.	Yield per Acre: Stover Tons	Pounds of stover for each pound of Shelled Corn
47,520	34,530	59	4.8	3.6
23,760	18,920	76	3.7	1.9
15,840	13,715	77	3.1	1.5
11,880	11,575	81	3.0	1.3
9,504	10,330	72	2.9	1.4
5,940	7,260	55	2.5	1.5

On the basis of analyses made at the Illinois Station during the progress of these experiments, Morrow and Hunt estimated that the corn stover contained 33 1-3 per cent moisture when it was weighed. They thus showed the following yield of bone-dry material per acre:

THICKNESS OF PLANTING—BONE-DRY BASIS.

Kernels per Acre	Stalks Harvested per Acre	Yield of Water-free Substance: Stover Lbs.	Kernels Lbs.	Total Lbs.
47,520	34,530	6,400	2,542	8,942
23,760	18,920	4,933	3,302	8,235
15,840	13,715	4,133	3,364	7,497
11,880	11,575	4,000	3,518	7,518
9,504	10,330	3,867	3,143	7,010
5,940	7,260	3,333	2,419	5,752

Still further and much more recent data from the Illinois Agricultural Experiment Station is available on the subject on the effect of the thickness of planting. This information is inserted below with the courtesy and permission of Professor W. L. Burlison, head of the Agronomy Department of the University of Illinois.

TOTAL WEIGHT OF CROP RESULTING FROM GROWING CORN IN HILLS SPACED AT DIFFERENT DISTANCES APART (1905-1917)
ILLINOIS AGRICULTURAL EXPERIMENT STATION

Distance of hills apart Inches	*Kernels per hill Number*	*Shelled corn per acre Pounds*	*Stalks per acre Pounds*	*Grain in total crop Per cent*
33 x 33	2	2559	4160	34.77
33 x 36	"	2884	4380	36.12
33 x 39.6	"	2850	4440	35.61
33 x 44	"	2688	4120	35.94
36 x 36	"	2946	4400	36.45
36 x 39.6	"	2806	4220	36.31
36 x 44	"	2699	4120	36.02
39.6 x 39.6	"	2828	4140	36.85
39.6 x 44	"	2486	3880	35.58
44 x 44	"	2111	3780	32.89
33 x 33	3	2722	4520	34.36
33 x 36	"	2957	4540	35.90
33 x 39.6	"	3018	4580	36.13
33 x 44	"	2850	3940	37.98
36 x 36	"	2873	4400	35.95
36 x 39.6	"	2996	4480	36.43
36 x 44	"	2873	4080	37.45
39.6 x 39.6	"	2929	4420	36.25
39.6 x 44	"	2822	4080	37.09
44 x 44	"	2677	3680	38.01

The following tabular summary shows total yield of dry matter in the corn plant not including roots, at other state agricultural experiment stations many years ago:

	Variety	*Dry weight per Acre Lbs.*
Geneva (N. Y.)	King Philip	7,918
Michigan		8,020
Missouri		7,892

The Effect of Shocking on Quality of Grain Produced:

The Indiana results reported in Bulletin 175 of the Indiana Experiment Station by Jones and Huston show clearly that shocking corn results in the recovery of a much larger dry matter weight than where corn is allowed to mature on the standing stalks. Corn stover harvested and cured in this way would, therefore, be much more valuable to the manufacturer than corn harvested from standing stalks which were cured in the field. It is also to be noted that less dirt would be gathered where the corn matured in the shock, which would likewise be an advantage to the manufacturer.

Some corn growers believe that the quality of grain produced when corn is cured in the shock is better than corn cured on the stalks. The Illinois Agricultural Experiment Station began studying this subject in 1927. This study has not gone far enough to permit making definite deductions, but the first year's work indicates that the assumption is correct that grain of higher quality is produced when corn is cured in the shock. The difference, however, is less in the Corn

Belt counties of the State than in the southern counties. At the Illinois soil fields located in the Corn Belt counties, the quality of grain from corn cured in the shock was 81.3 while that cured on the stalks standing in the fields was 78.9. At the soil fields in the southern part of the State corn cured in the shock had a quality of 74.2 while the grain cured on the standing stalks had a quality of 60.5.

Utilization of Corn on the Farm:

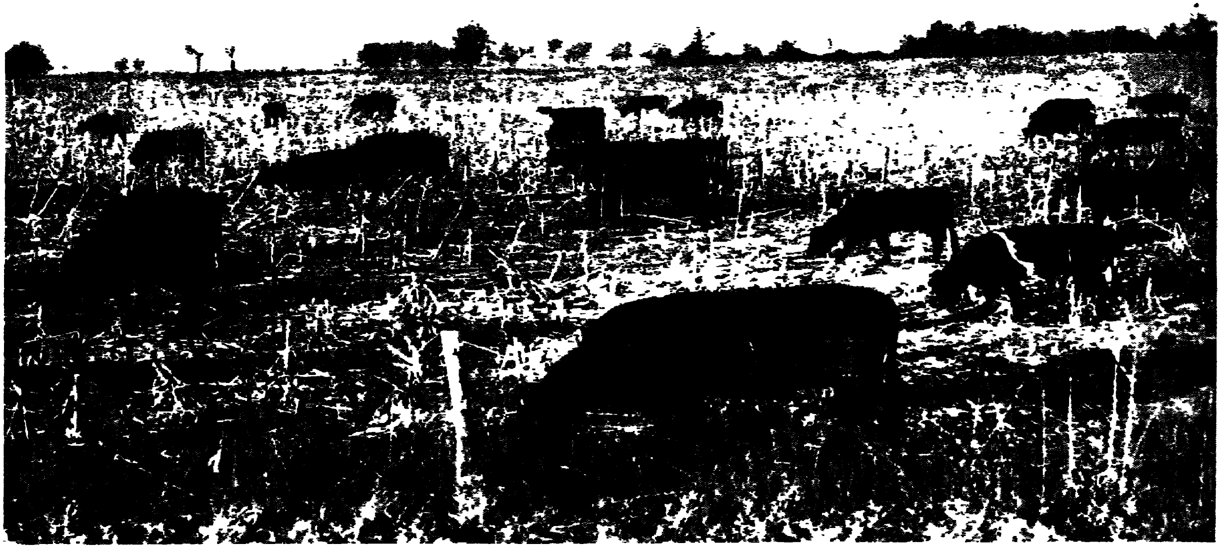
The Division of Crop and Livestock Estimates of the Department of Agriculture has compiled estimates during the past four years showing the proportion of the annual corn crop actually harvested for grain, the proportion used for silage and that used for grazing by animals ("hogged off," etc.) and for forage. The proportions for the principal Corn Belt States and for the United States were averaged for the author by Mr. Joseph A. Becker of that division and are as follows:

	Harvested for Grain Per Cent	*Cut for Silage Per Cent*	*Grazed by animals and used for forage Per Cent*
Ohio	84.25	6.70	9.05
Indiana	84.10	4.03	11.87
Illinois	89.23	3.62	7.15
Iowa	83.48	2.47	14.05
Missouri	91.20	1.00	7.80
South Dakota ...	66.80	1.52	31.68
Nebraska	88.18	.45	11.37
Kansas	88.50	1.80	9.70
Kentucky	94.35	1.00	4.65
United States ..	84.35	4.20	11.45

Photograph J. C. Allen

HOGGING DOWN CORN

This practice saves labor in corn harvesting and hog feeding. More than 11 per cent of the corn grown in Iowa is harvested by animals.



Photograph J. C. Allen

CATTLE IN CORNSTALK FIELDS

Custom gives a value of $1 per acre rent for this sort of cornstalk utilization.

Of course there are fluctuations from year to year in the relative proportion of the uses to which the crop is put, depending on its condition and other factors. As a rule the proportion of the corn crop which goes into the silo is much larger in the states north of the Corn Belt than in the Corn Belt proper. In the states beyond the Missouri River, a larger proportion of the crop is utilized for forage than in the states east of the Missouri, while in the South almost the entire crop is harvested for grain.

Manufacturing Material Available from the Corn Stover Crop:

Taking the average annual utilization of the corn crop for grain production in Illinois as 89 per cent and the average annual crop for the past four years in that State, based on Department of Agriculture estimates, as 316,492,000 bushels, using the stover-grain ratio of 143 per cent which was found for the Illinois soil fields receiving no soil treatment, we may estimate that the average annual production of corn stover in Illinois available for manufacturing purposes for the four years 1924-1927 exceeded 11 million tons.

Morrow and Hunt used a factor of 33 1-3 per cent moisture in determining the dry matter content of stover produced in their experiments. The Illinois stover yields are field-dry weights and this factor may be applied in determining the annual production of bone-dry material in corn stover in Illinois at present, because the same method of weighing stover is still used by the Experiment Station. The estimate which

we get in this way is 8 million tons in round numbers as the total amount of moisture-free stover in the State as a whole.

Data compiled by Davidson and Collins of the agricultural engineering section of Iowa State College for the corn crop of Iowa in 1925 indicate the moisture-free weight of corn stover in Iowa in that year as over 10 million tons.[1] Davidson remarks:

"In many sections of Iowa the corn area makes up one-third of the total area. Thus, within a radius of 10 miles from a selected factory site, there will be found 133,000 acres of corn. If the yield of stalks is 1¼ tons per acre, the total tonnage available within the radius of ten miles will be 166,000 tons.

"Dr. O. R. Sweeney estimates that a factory producing wall board could be successfully operated on 30 tons of stalks per day, or 10,950 tons. This amount would be less than 7 per cent of the total tonnage within a radius of ten miles."

In view of the variation in yields of stover and in the stover-grain ratios from experimental results reported by different Corn Belt experiment stations, it is a waste of time to attempt to calculate the actual yields on farms in the remaining states for which data have been presented in these pages. However, the probabilities are that the total annual production of corn stover in these nine states which might be used for manufacturing purposes is at least 50 million tons with a dry-matter content of fully 33 million tons. This

[1] Acreage 10,832,559; 81 per cent harvested for grain—8,701,910. Yield of stover, 1¼ tons per acre, moisture-free.

amount of bone-dry raw cellulosic material is much more than sufficient to supply pulp for the 12 million tons of paper used in the United States.

Taking the United States as a whole, the average annual corn crop for the past four years 1923-1927 was 2,676,220,000 bushels. With 84 per cent of the crop harvested for grain and a stover-grain ratio of 150 the total annual production of stover would be 94 million tons, containing not less than 62 million tons of bone-dry material on a basis of 33 1-3 per cent moisture in the stover at the time the grain was harvested.

CHAPTER VII

WHAT CORNSTALKS ARE WORTH TO THE MANUFACTURER

THERE is gold in sea water but the cost of getting it out is more than the gold is worth.

The gold in the despised cornstalk has tempted chemists and other experimentalists for more than 150 years. A German, Jacob Christian Schaeffer, suggested Indian corn as paper-making material in 1765. In 1802, B. Allison and J. Hawkins took out an American patent for a process of making paper out of corn husks. This appears to have been the first definite effort of this kind. Twenty years ago the United States Department of Agriculture made an exhaustive study of the corn plant and other annuals as a source of paper. The Department did not stop with laboratory investigations but carried their research into actual mill operations. The report of this study was published as a pamphlet in which five different kinds of paper were used.

Like the production of gold from sea water, nothing came of these efforts because the resulting products cost too much to make or because as good or better things could be produced for the same or less cost from cheaper sources of raw material.

Paper from Farm Wastes:

Perhaps this is as good a place as any to say something in detail about the production of paper from other material than wood pulp, especially farm wastes.

An enormous amount of research work has been done on the use of vegetative material for paper manufacture. It seems that almost every fibrous plant has been studied somewhere in the world if it has given promise of yielding fiber in sufficient quantity and cheaply enough to warrant its use for paper-making. A bibliography of the subject, which its author regards as incomplete, was published a few years ago by a firm of consulting chemists and covers 148 octavo pages of printed matter.

The earliest source of paper is supposed to have been the papyrus plant of Egypt, the process of making paper from it dating back to about 1700 B.C. Cotton and linen paper followed, with straw and wood-pulp paper coming much later.

Straw was used for paper-making in America before wood was used, and some of our great paper mills got their start in that way, abandoning straw and turning to wood when the possibilities of the latter material became known. Some of the finest paper known is made of Esparto, a grass found in Spain and North Africa, which is extensively used in Europe.

Any plant which makes a heavy growth of fibrous material is a potential source of paper. Sugar-cane bagasse has been found to be exceptionally valuable by

many investigators. A factory is already producing cellulose pulp from bagasse in Cuba. Bamboo and its relatives are already being used in some parts of the world and will some day be extensively drawn upon. Mr. G. S. Witham, Sr., in his book, "Modern Pulp and Paper Making," says an area of bamboo of "only about 16 square miles would be required to supply a 100-ton mill indefinitely." Bamboo has been established in the South but has not yet found a market. Jute, manila, hemp, rags, waste paper all contribute something to the world's supply of paper. The supply of waste paper in the United States has become an important factor in our paper industry, 1,855,000 tons being used as compared with 278,000 tons of rags. The possibilities of seed-flax straw are discussed in Chapter X.

When the demand for paper began to increase rapidly a century ago, the available supplies from rags, cotton, straw and similar materials soon proved insufficient and the price of paper threatened to become prohibitive. A source of cheap and abundant raw material was imperative. That brought wood pulp into use, and made cheap paper possible.

The enormous development of printing and publishing could not have been accomplished during the past seventy-five years had it not been for the huge supplies of wood available for paper-making. Newspapers, magazines, books, music, literature, art and education could by no means have been brought to their present standards if we had not had forests to draw upon for paper-making material.

The demand for paper continues at a constantly increasing rate and the price of pulp wood has risen to so high a point that cheaper sources of raw material are again being sought. While the alarms about an impending paper shortage may be discounted, there is no doubt that many paper makers are in a receptive frame of mind to consider other sources of raw material if they promise to be cheaper than wood. The high price of paper-base stock a hundred years ago sent the paper industry into the forests. The high prices of pulp-wood to-day are tempting the men in the paper industry to stroll through the grain fields.

As we observed in Chapter IV, taking the Nation as a whole, with Canadian supplies of spruce available to the paper manufacturer on this side of the line, an adequate supply of paper seems assured, particularly where the owners of woodlands in the United States and Canada have fostered the reproduction of trees. The possibility amounting almost to certainty that newsprint will in time be made out of southern pine or hardwood also tends to prevent the present writer from becoming panicky about paper supplies.

It is a fact, however, that individual mills in many cases have been forced into serious circumstances by reason of the decline in nearby supplies of pulp-wood, and some mills are being abandoned. Many new paper mills have been recently established on the Pacific Coast, but an established pulp or paper manufacturing company cannot contemplate that solution of its raw material supply with complacency. The capital required for a paper mill has been estimated at about $30,000

for each ton of daily capacity, so that a mill producing 100 tons of pulp daily will need at least $3,000,000 to start on. Obviously, such a volume of fixed capital cannot be moved around.

At present the principal use of straw for manufacturing purposes is for the manufacture of paper boards and 9-point corrugated board. Figures from the Forest Service give 355,000 tons as the amount of straw used annually in paper manufacture in the United States. These figures also indicate the following percentages of raw material used for the manufacture of boards:

Mechanical pulp	5 per cent
Sulphite pulp	8 " "
Sulphate pulp	7 " "
Waste paper	64 " "
Straw	14 " "
All other	2 " "

The situation as to the use of straw has apparently changed since these figures were compiled. A recent estimate given to the writer by the Paper Board Industries Association indicates an annual consumption of about 250,000 tons of straw in the manufacture of boards.

The utilization of straw or cornstalks may be a way out for the paper manufacturer who does not care to go out of the business and does not want to move West.

The story of the cost of straw for manufacture is a short and simple tale. The business is largely in the hands of local owners of baling-presses who travel around the country, buying straw in the stack from farmers and then selling it to the manufacturers. The

price which farmers get varies from 75 cents a ton in the stack to $1.50 a ton. Baling costs are quite uniform. In most sections of the Middle West baling costs $3 per ton. Beyond the Missouri River the charge is sometimes as low as $2. The straw costs the manufacturer from $7.50 to $14 or $15 by the time it is delivered to him. The Straw Products Company of St. Paul Park, Minn., at last reports, was paying $9 a ton for straw delivered to the plant.

In spite of the extensive research which has been done on other paper-making materials besides wood, some paper authorities contend that the amount of chemical research which has been spent on cereal straws as a source of paper is much less than has been spent on wood.

Some study of processes to make paper out of straw is under way in America. In one case the inventor claims a yield of 50 to 52 per cent, but, unfortunately, the conversion costs are high, on account of the chemicals used, and practical means for the recovery of the chemicals have not been perfected.

The increase in the distance between the supply of paper-base stock and the printing press cannot help but add to the cost of paper, and this fact lends weight to the suggestion that the manufacture of paper from cereal by-products should not be brushed aside as impractical. Freight costs may give an advantage to the manufacture of pulp in the Middle West, especially if it is found practicable to mix straw pulp or cornstalk pulp with wood pulp for the manufacture of a satisfactory grade of paper.

It is entirely a question of dollars and cents. Mr. W. G. MacNaughton, formerly of the American Paper and Pulp Association, gives these figures. The paper manufacturer in the United States who buys his pulp-wood in Canada will pay per cord:

Stumpage	$ 2.00
Logging and delivery to railhead or river	6.00
Transportation	4.00
Total	$12.00

A yield of 1,000 to 1,200 pounds of chemical pulp per cord of wood will be obtained. From a ton of straw the yield will be about one-third or somewhat better. So two cords of wood are worth as much as three tons of straw if there is no material difference in conversion costs. At $12 a cord for pulp-wood, straw is therefore worth $8 f. o. b. mill, and when wood costs $15 a cord, straw will be worth $10.

Manufacturers of paper to whom the supply of wood pulp is a problem are seriously considering the use of straw, but are hesitating for several reasons. Thus far, the processes of making paper out of straw have been more expensive than wood-pulp manufacture. The chemicals are costly and their recovery is difficult.

Even in the strawboard industry the tendency to discontinue the use of straw is pronounced, and waste paper has entirely displaced straw in some mills. The "straw belt," the region from which manufacturers draw their supplies of raw material, is slowly moving westward which brings another complication into the

picture—the smaller supply of water as one goes west into the Wheat Belt.

Doubtless another reason for the decline in the use of straw for manufacturing is the realization by farmers in states east of the Mississippi River that straw is worth more on the farm than farmers have usually received for the straw that goes into manufacture. Oats, wheat and barley straw make excellent bedding and are good roughage for cattle when properly combined with other feeds. The cattle men in Scotland fatten cattle every year on such a ration and many Pennsylvania farmers do the same, following the leadership of Pennsylvania State College, which institution showed many years ago that a ration of wheat straw, corn silage and cottonseed meal was an economical one for fattening steers. The case of cornstalks on the farm is different, for many reasons, as we shall see in the next chapter.

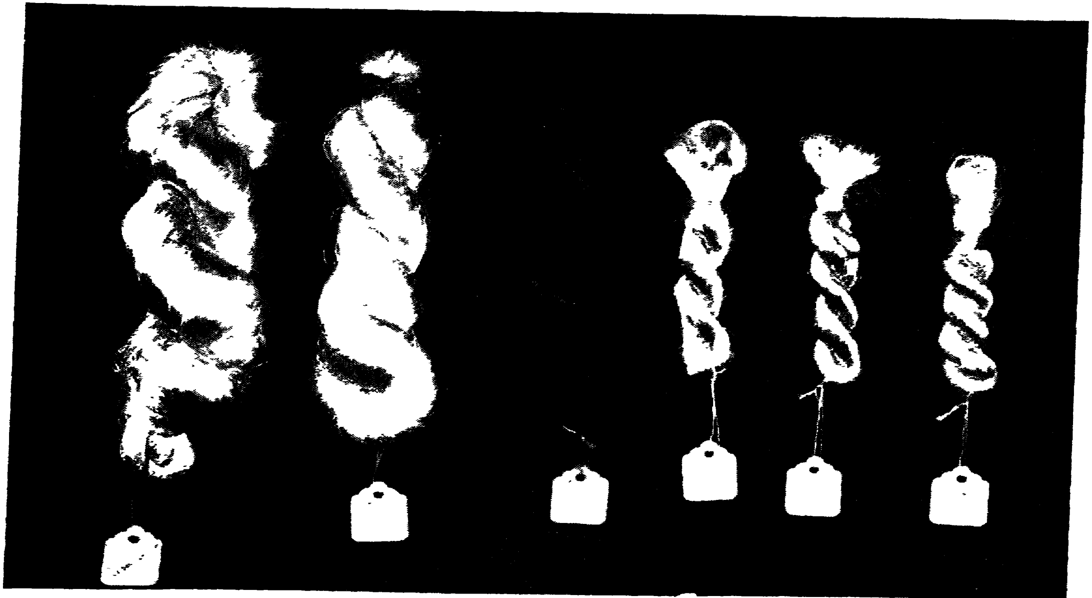
The investigation of the United States Department of Agriculture twenty years ago was somewhat like the "successful operations" that surgeons describe, where the patients died. The Department's attempts to make paper out of cornstalks was a success technically but a failure commercially. The pith fibers in the cornstalks were too small, with too low a felting value, to be of much use for paper and the cost of separating the pith from the outer stalk or bast fibers was excessive. The cornstalk pulp produced gave best results when it comprised only a relatively small proportion (about 20 per cent) of the pulp from which the paper was made.

If a saleable by-product could have been developed

this Government effort of twenty years ago might have led to actual commercial operations which would have definitely established a profitable paper-making industry using cornstalks and other farm wastes as raw material. In the course of manufacture, a molasses-like product was recovered which was high in protein and therefore promised considerable value as a livestock feed. Experiments were made to test the value of this product in feeding animals, but it appeared that it contained mineral salts which the animals did not like. The expense of removing these salts from the product was so great as to be prohibitive.

The price of raw cornstalks, and the expense of the operation, without a by-product that would carry part of the expense of manufacturing, put the cornstalk out of the running as a source of paper at that time. A method of using cornstalks for paper was thus shown, but it did not pay. This led to the common remark one hears among paper men to-day, that "Anybody can make paper out of cornstalks, but nobody can make any money out of it."

The arguments of the Cornstalk Products Company's chemists disclose a new angle to the use of cornstalks for this purpose. Their consulting and research chemist, Dr. John E. Jackson, contends that the processes formerly used with cornstalks were similar or identical to those used in the manufacture of paper from wood. Wood has become "lignified," according to Dr. Jackson, and requires rather severe treatment to separate cellulose from the lignin. If such harsh treatment is applied to field-crop wastes the cellulose struc-



Photograph courtesy of Cornstalk Products Company

RAYON MADE FROM CORNSTALKS

Cellulose pulp made from cornstalks has quite as wide a range of usefulness as cellulose from other raw materials. In the course of its manufacture from cornstalks, valuable by-products may be recovered.

Photograph courtesy of Cornstalk Products Company

BALED CORNSTALKS EN ROUTE TO THE FACTORY AT TILTON, ILL.

Good roads are essential to low-cost cornstalks. The average charge for hauling baled cornstalks in Vermilion County, Ill., for a 15-mile haul in 1927 was 8.6 cents per ton mile.

ture, perhaps the cellulose molecule itself, becomes broken up and the operation is certain to be unprofitable on account of the losses sustained. In treating farm wastes the chemist is dealing with products in which the extent of lignification is far less than in wood. Lignin is present in all plant products, but it is much more easily removed from farm wastes than from wood. Therefore milder chemical treatment is necessary, which, according to Dr. Jackson, should make it less expensive than the manufacture of pulp from wood. The pith cells are cited by nearly every paper chemist as an important technical obstacle to the use of cornstalks. They do not worry Dr. Jackson. He points out that all paper has some "filler" added to it and the pith acts as filler in paper made from cornstalks with the process which Cornstalk Products Company uses. The nodes, which have bothered chemists working with straw, do not disturb Dr. Jackson. He claims that the new process digests 80 per cent of them and that the undigested nodes are so large that they are easily screened out.

It is evident that if Jackson can carry his chemistry through into commercial production, he will effect something almost akin to a revolution in the manufacture of paper and other cellulose products in America.

Still another factor which changes the picture materially from that which was seen before the War is the development which grew out of the war demand for cellulose from any available source. We were left at the close of the War with a new supply of industrial

products made of cellulose, new markets opened up, and all sorts of attractive things offered for sale. This has led sober-minded chemists to predict that growing cellulose may be the big development in farming during the next fifty years. Not only paper, but a whole range of things, from wallboard to "silk" stockings, offer the cellulose manufacturer a market in 1928 that nobody dreamed of in 1908.

The author is not a chemist and he will leave it to the chemists to fight out the relative value of various processes for manufacturing cellulose out of the multitudinous variety of raw materials available. He is strongly of the opinion that the utilization of field crop by-products for cellulose production will depend upon an even more fundamental factor than the relative value of chemical processes. Let us assume that the manufacturing costs in the production of cellulose from farm wastes and wood are the same, and that the products manufactured are equal in value. It then appears to be perfectly plain that the cost of the raw material delivered to the factory will decide whether cornstalks and similar things are to compete actively with wood.

Up until the year 1927 nothing was accurately known of the probable cost of cornstalks to the manufacturer, or even to the farmer who grows them. That information is now available.

Cost of Collecting Cornstalks:

Professors J. B. Davidson and E. V. Collins, of the agricultural engineering section of Iowa State College, undertook to answer this question and were the first

men to get accurate engineering data on the cost of collecting cornstalks. During the winter of 1926-7 they experimented with various methods of collection and found the most economical outfit to be one of their own contrivance which harvested the stalks from fields where the corn had already been husked in the usual manner. It was a combination of a mower, hay-loader and hay baler hauled by a tractor which made possible a continuous operation. Details of the costs of collection with this outfit were as follows:

Cost of equipment with modifications:	
Baler or press	$565.00
Loader	135.00
Mower	86.00
Modification estimate	114.00
Total cost of outfit	$900.00
Annual cost, consisting of interest, depreciation and repairs	$200.00
Assuming 200 hours' use, cost per hour will be..	1.00
Cost of 15-30 tractor per hour	1.50
Foreman per hour	1.25
3 men @ 50c per hour each	1.50
Total cost per hour	$ 5.25
Cost per acre (2½ acres per hour)	2.10

Assuming a yield of 8/10 ton per acre, moisture free, the cost per ton will be as follows:

Harvesting per ton	$2.62
Cost of baling wire	.50
Cost of harvested stalks at farm	$3.12

To these costs should be added an allowance for transportation, for feed and fertilizer removed from the farm and for the farmer's profit. An average haul of 8 miles was estimated and the cost of transportation distributed as follows:

Cost of first ton-mile	$ .30
Cost of additional ton-miles 7 @ 20c	1.40
Total for transportation..	$1.70

All these costs were figured on a very conservative basis. Labor charges are high for farm labor and considerable labor could be saved by using an automatic bale tie, two men being needed to tie bales with this outfit. The transportation charges are higher than the average in the Upper Mississippi Valley. The Bureau of Public Roads estimates that the cost of trucking in this section will average 8½ cents per ton-mile for all kinds of roads. The charge at this rate for eight miles would be 68 cents per ton as against $1.70 in the Iowa figures. A factory buying cornstalks from farmers and doing the hauling would have to add something to this figure for loading and unloading.

The Davidson-Collins figures were open to but one criticism. In a sense, they were laboratory estimates, subject to the cold check of commercial experience. This was made possible in the fall of 1927 by the extensive harvesting operations of the Cornstalk Products Company in Vermilion County, Illinois, which were organized and directed by Harvey J. Sconce, manager of the company's raw material production department.

Sconce laid his plans as thoroughly as if he were embarking on an elaborate corn-breeding investigation. He conferred first with engineering heads of farm implement companies and decided to prove, by field tests, the relative efficiency of every type of corn-harvesting machinery on the market, as well as special implements developed for the corn borer campaign which might be adaptable for assembling cornstalks.

Sconce realized that farmers could not be expected to do this pioneering work; so he organized a staff of trained farm mechanics and engineers to handle machines and direct labor. Tractors, horses, mules, hay-balers and trucks were hired from farmers, but corn-harvesting machinery, which is not in general use in the Illinois Corn Belt, was purchased by the company.

After trying one- and two-row corn-binders, Sconce bought more than fifty of the one-row type. Three horses or mules to a binder, or one tractor hauling two binders in tandem, proved to be the economical unit. Three binders would cut eighteen to twenty-seven acres a day. About 4,000 acres of corn were harvested and shocked in this manner before the work was stopped by heavy fall rains.

After the weather improved, and corn had been thoroughly cured on the stalk, grain harvesting and cornstalk collecting were combined. The standing stalks were cut in the field with corn harvesters and the bundles hauled to the farmer's crib. There they were run through a husker-shredder which delivered the ears to the farmer's wagon whence a portable elevator conveyed them to the crib, while the shredded stover was

delivered to a hay baler at the rear of the machine. By this method the farmer got his corn husked for the stover and the company got the cornstalks for the cost of harvesting the corn, husking, shredding, baling and hauling the bales to the factory.

This particular method—husking and shredding direct from the field—was an emergency measure adopted to get the harvesting done after the weather permitted taking machines into the fields. The better plan and the one which will probably be adopted in future, involves shocking the corn early, as we shall see a few paragraphs later on.

The company used all available forms of field power —horses, mules and tractors. In all, 10,000 tons of cornstalks were baled and hauled to the factory at Tilton.

The corn harvesting season of 1927 was one of the most difficult for the purpose of such a determination that could be imagined. The crop was light and during October heavy storms blew the corn down so that a considerable amount of it was flat on the ground, making it exceedingly difficult to gather. Storms also occurred late in November which made it impossible to get into the fields for nearly a month after that. In spite of these obstacles the company found that with an average haul of fifteen miles the average cost of the 10,000 tons of baled stalks delivered to the factory was less than $8 per ton, including farmers' compensation. Stalks were hauled from fields twenty miles from the plant at a cost as low as $5.68 per ton. The company believes that in a normal year the average cost should

not exceed $6 and that it might be as low as $5 per ton delivered at the factory without reducing what farmers get out of it.

The Maizwood Products Corporation, which has built its first factory at Dubuque, Iowa, to manufacture wallboard out of cornstalks, collected several thousand tons of stalks in Iowa from January 1 to April 15, 1928.

The farmer was paid $1.50 per ton for the corn stover in the field and the company also hired farm help and farm teams and equipment to rake up the cornstalks and haul them to the baler. The company had its own power balers and hired farm help to assist in the baling when possible.

In the better corn areas in Iowa from which the Maizwood people gathered their raw material the yield of corn stover is said to have been one to two tons per acre. From this fact the Maizwood Products Corporation estimates that farmers who sold cornstalks to the company obtained from $3 to $5 per acre, when the amount paid for farm labor and equipment was added to the amount paid for cornstalks. It is reported that these farmers are well satisfied with their initial experiment in this new venture.

Maizwood Products Corporation nas given out no costs of cornstalks delivered at the factory, but the company hopes to be able to lay them down in its yards at the factory for $5 to $6 per ton.

Although the crop season of 1927 was exceptional from start to finish and may not soon be repeated, the uncertainty of weather conditions during the months

in which corn is harvested will always be an important factor in cornstalk manufacturing operations.

The company utilizing cornstalks will probably find its most economical method of collection to be cutting the corn as soon as the grain is out of danger from frost, shocking it, and after the stover has matured in the shock, hauling it to the husker-shredder whenever the weather permits.

We saw in Chapter VI that evidence from the Indiana Agricultural Experiment Station indicates that curing corn in the shock prevents a loss of one-third in the bone-dry weight of corn stover compared with that of stover matured in the field with the stalks standing uncut. It was also noted in the same chapter that grain from corn matured in the shock will probably be of better quality than grain matured on the standing stalk. Likewise it is shown elsewhere in this book that cutting and shocking corn has a beneficial effect on plant disease and insect pest control.

The harvester-husker-shredder-baler method reduces man labor to a minimum, and every one who ever handled cornstalks in the field or got a couple of them stuck on a four-tined manure fork will appreciate the advantage of that. It leaves the fields in good condition for the succeeding crop and removes a possible harbor of plant diseases and insect pests. It returns a better quality of stover and more of it, and possibly better grain also. It delivers the farmer's corn where he can easily transport it to his crib and shreds the corn stover, thus making it the first step in the manufacturing process. Incidentally it may be remarked

that, according to the Cornstalk Products Company, shredded stover weighs 100 pounds per bale, as against only 60 pounds per bale for unshredded whole cornstalks. The cost of shocking is the one obstacle to this method of collection. The shocking method of harvesting corn is good manufacturing practice and good farm practice. Both manufacturer and farmer will want to know if it is the cheapest method in the long run. Perhaps together they can work the answer out to their mutual satisfaction.

The prevailing custom in Ohio and eastern corn-growing States is to cut and shock corn and husk out of the shock, but the practice has never been resorted to to any great extent in Illinois or Iowa on account of the labor required. Davidson and Collins give the rate in Iowa for shocking corn, twelve hills square, as 12 to 15 cents per shock, or $2.96 per acre at 12 cents a shock and $3.75 at 15 cents. A mechanical shocker has been suggested as an attachment to the corn harvester. In case it is feasible from an engineering standpoint, the cost of hand shocking may be set as a figure against which an operator may calculate the economy of machine shocking. The numerous advantages in favor of shocking and greater independence of the weather should also be estimated as credit items against the additional expense of this method of collection.

It is not to be supposed that the last word has been said on the economy of collecting cornstalks, in spite of the success of the 1926 and 1927 undertakings by which Davidson and Sconce have made such distinct

contributions to agricultural engineering. Various refinements are obviously possible in the Cornstalk Products Company's husker-shredder method, the most important one being the speeding up of the operation. As the outfits were assembled in the fall of 1927, the baler was a "bottle-neck" which slowed up the entire process. The husker-shredder could be run no faster—could take no more corn-fodder—than the baler could deliver bales of shredded stover. The baler, an ordinary hay baler, could not be crowded.

The Celotex Company found it necessary to devise special types of balers for bagasse and something of the sort should be worth while in collecting cornstalks. The automatic bale tie suggested by Prof. Davidson would permit the elimination of one man in the baling gang. More capacity in the baler would make possible driving the husker-shredder at full capacity or might even make larger husker-shredders practical and greatly increase the output, all of which would tend to reduce the net cost of baled cornstalks.

Transportation Costs:

We have seen that Prof. Davidson made an allowance of $1.70 per ton for hauling one ton eight miles in Iowa. This is an average of 21¼ cents per ton-mile and considerably more than double the Bureau of Public Roads estimate of 8½ cents per ton-mile as the average hauling charges in the Upper Mississippi Valley. The hauling charges established by the Cornstalk Products Company, according to Mr. Sconce, in their operations in 1927 ranged from 15 cents per ton-mile

for a one-mile haul to 6 cents per mile for a thirty-mile haul. The cost for a fifteen-mile haul was 8.6 cents per ton-mile, which is very little different from the estimate of the Bureau of Public Roads. It should be noted that Vermilion County is blessed with good roads.

With the enormous supply of raw material available within easy hauling distance, it is quite likely that no other method of transportation will be resorted to except truck hauling or its equivalent. Rail shipments will probably be little used but may be needed on occasion for longer hauls than twenty miles. For reference there are inserted here figures compiled by Mr. E. E. Forbes, Traffic Manager of the United States Department of Agriculture, showing freight rates on hay and straw at selected points throughout the Corn Belt, rates being given for each commodity for distances of practically 50, 100, 150 and 200 miles. It is assumed that baled cornstalks would take similar rates to those charged by the railroads for hay and straw.

From	*To*	*Distance Miles*	*Commodity*	*Carload Rates Cents per Cwt.*	*Minimum Carload Weight Pounds*
Peru, Ind.	Columbus, Ohio (Pa. R.R.)	47	Hay	25	20,000
Eldorado, Ohio	do	99	do	19	do
Knightstown, Ind.	do	160	do	22	do
Clayton, Ind.	do	199	do	25½	do
Peru, Ind.	do	47	Straw	25	do
Eldorado, Ohio	do	99	do	19	do
Knightstown, Ind.	do	160	do	22	do
Clayton, Ind.	do	199	do	25½	do
LaFayette, Ind.	Danville, Ill.	46	Hay	15	do

From	*To*	*Dis-tance Miles*	*Commod-ity*	*Carload Rates Cents per Cwt.*	*Mini-mum Carload Weight Pounds*
Peru, Ind.	Columbus, Ohio (Wabash R.R.)	47	Hay	25	20,000
Peru, Ind.	do	99	do	19	do
Ft. Wayne, Ind.	do	155	do	23	do
Montpelier, Ohio	do	204	do	25½	do
Lafayette, Ind.	do	46	Straw	15	do
Peru, Ind.	do	99	do	19	do
Ft. Wayne, Ind.	do	155	do	23	do
Montpelier, Ohio	do	204	do	25½	do
Clearwater, Minn.	Minn'polis, Minn. (Gt. Northern Ry.)	51.6	Hay	9½	do
Sauk Center, Minn.	do	105	do	13	do
Evansville, Minn.	do	148	do	15½	do
Barnesville, Minn.	do	200	do	17½	do
Clearwater, Minn.	do	51.6	Straw	9½	do
Sauk Center, Minn.	do	105	do	13	do
Evansville, Minn.	do	148	do	15½	do
Barnesville, Minn.	do	200	do	17½	do
Delaware, Iowa	Dubuque, Iowa (I. C. R.R.)	50	Hay	9	do
Cedar Falls, Iowa	do	100	do	10½	do
Alden, Iowa	do	150	do	13½	do
Tara, Iowa	do	199	do	16½	do
Delaware, Iowa	do	50	Straw	5½	do
Cedar Falls, Iowa	do	100	do	8	do
Alden, Iowa	do	150	do	9½	do
Tara, Iowa	do	199	do	11	do
Scranton, Iowa	Ames, Iowa (C. & N. W. R.R.)	50	Hay	9	do
Arion, Iowa	do	101	do	11	do
Council Bluffs, Iowa	do	158	do	14	do
Fremont, Neb.	do	197	do	19	19,000
Scranton, Iowa	do	50	Straw	6½	20,000
Arion, Iowa	do	101	do	9	do
Council Bluffs, Iowa	do	158	do	10½	do
Fremont, Neb.	do	197	do	19	19,000
Preston, Neb.	St. Joseph, Mo.	49	Hay	10½	22,000

From	*To*	*Distance Miles*	*Commodity*	*Carload Rates Cents per Cwt.*	*Minimum Carload Weight Pounds*
Peru, Ind.	Columbus, Ohio (Burlington R.R.)	47	Hay	25	20,000
Burchard, Neb.	do	102	do	14	do
Endicott, Neb.	do	149	do	14½	do
Hardy, Neb.	do	199	do	17	do
Preston, Neb.	do	49	Straw	10½	do
Burchard, Neb.	do	102	do	14	do
Endicott, Neb.	do	149	do	14½	do
Hardy, Neb.	do	199	do	17	do

The Illinois Central Railroad Company established rates on cornstalks in bundles or bales to Dubuque, Iowa, from points in Illinois, effective April 30, 1928. The minimum carload weight is 20,000 pounds. For distances of fifteen miles and under, class rates apply. Rates for greater distances are as follows:

	Rates in Cents per 100 Pounds
To Dubuque, Ia., from I.C.R.R. Stations in Illinois for distances of 25 miles and over 15	9
50 miles and over 25	10
75 miles and over 50	11.5
100 miles and over 75	12
125 miles and over 100	13.5
150 miles and over 125	14
175 miles and over 150	14.5
200 miles and over 175	15
225 miles and over 200	16.5
250 miles and over 225	18
275 miles and over 250	18
325 miles and over 275	19.5

The data presented in Chapters IV, V and VI show clearly that the corn plant will produce raw cellulosic material at a rate which compares favorably with the annual growth of trees. The data in this chapter show that this material can be brought together at a cost to the manufacturer which puts cornstalks in a favorable cost relation for the manufacture of cellulose products. Data compiled by Prof. Davidson show clearly that baled cornstalks cost at the farm without any allowance for feed or fertility value or the farmer's profit slightly more than $3 per ton. The actual commercial operations of the Cornstalk Products Company show that the delivered cost to the manufacturer need not exceed $8 per ton and may be materially less, including reasonable compensation to the farmer for feed and fertility value and profit. In the next chapter we shall consider the cost of these crop wastes to the farmer.

CHAPTER VIII

WHAT CORNSTALKS ARE WORTH TO THE FARMER

It is perfectly obvious that the manufacturer proposing to utilize cornstalks as raw material will be unable to get them unless farmers receive what they regard as a fair price for them. Even if the manufacturer should organize an extensive farming operation of his own for the purpose of being assured of an adequate supply of raw material, his financial structure would break down if he did not have an intelligent idea of what his cornstalks cost him to produce.

How much cornstalks are actually worth to a farmer in dollars and cents cannot be satisfactorily determined on the basis of any research data known to the author. This problem will probably be worked out by the "trial and error" method before it is solved by research methods.

It is common practice in the central part of the Corn Belt to rent cornstalk fields for pasture for $1 an acre after the corn is harvested, the farmer thus also getting the benefit of manure dropped on the field. If the cornstalk yield is 1 to 2 tons per acre, custom would thus assign a feed value of 50 cents to $1 a ton plus such additional value as might be placed on the manure—say a total value, including both pasture-rent and manure credit, of 75 cents to $1.25 a ton. The

amount of the corn crop in the entire country which goes into the silo is less than 5 per cent, and that which is grazed by animals (hogged off) and grown for forage is 11.45 per cent; the remainder, 84.35 per cent, is harvested for grain. In the nine leading Corn Belt States, only 2.35 per cent of the crop is put into the silo, 11.83 per cent is grazed or grown for forage and 85.85 per cent is harvested for grain.

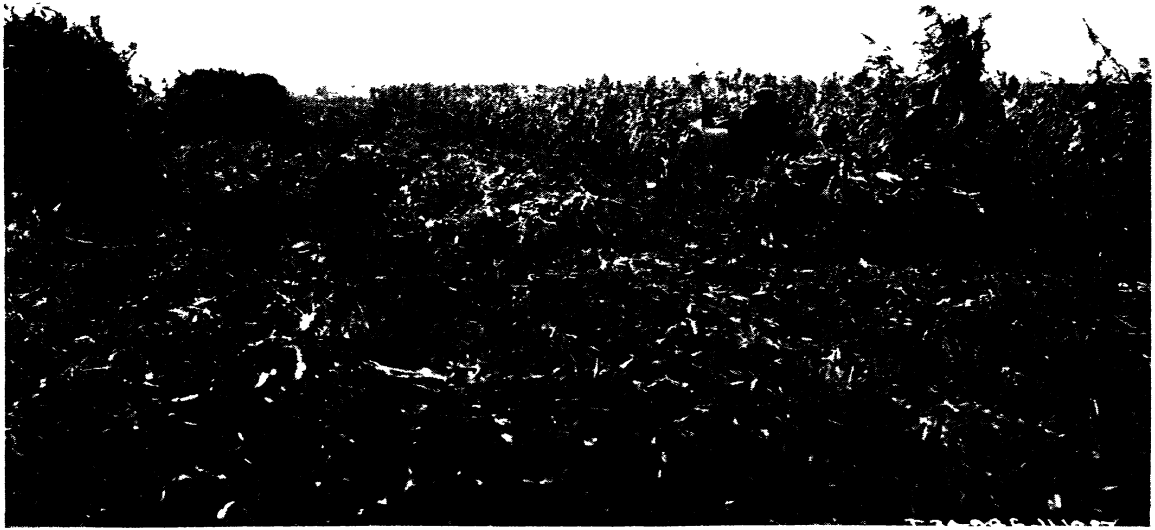
No fault can be found academically with the logic of the farmer who firmly takes the stand that he will permit no roughage to leave his farm except "on four legs," but, speaking practically, the country could not absorb all the meat and dairy products that could be made if all the cornstalks and straw produced in the Corn Belt were fed to livestock. As we have seen, the leaves and husks contain most of the feed value in cornstalks, and it seems that practical methods of taking them off the stalk can be devised, in which case they would have a value about equal to that of timothy hay. Cornstalks (stems) can be put into condition for animals to eat by cutting and putting them into the silo, or by shredding, but these are expensive, laborious processes. The stem of the corn plant has fulfilled its purpose the moment the ears are husked.

The information on the fertility value of cornstalks is still less satisfactory than that on its feed value. All of the statements on this point have been based on straight chemical analyses of nitrogen, phosphorus and potassium present. Going values of these elements as indicated by local cost of fertilizers at the time the analyses were made, were taken to estimate the money

Photograph courtesy of U. S. Dept. of Agriculture

PICKING CORN BY HAND

A hard, cold, blistering job. The stalks remaining in the fields are used for winter pasture or entirely wasted.



Photograph courtesy of International Harvester Company

CORN HARVESTERS AT WORK

To keep raw material costs within reasonable limits, the first step in the utilization of cornstalks for manufacture is machine harvesting. The work shown in this picture was done late in the season. If corn is cut and shocked as soon as the grain is ripe, larger yields of corn stover will be obtained and the grain will probably be of better quality.

value of the fertilizing constituents removed from the soil in a ton or an acre of cornstalks. No attention was paid to the availability of the fertilizing constituents, and this discrepancy throws the assumed values out of line, especially in the case of nitrogen. It is now known that the microörganisms which decompose cellulose do not act in the absence of nitrogen. Therefore cornstalks will decompose only if nitrogen is added to them, or if they are plowed under, at the expense of the nitrogen already in the soil. This fact has been so well established that soil chemists studying the decomposition of cellulose add stated amounts of nitrogen in proportion to the amounts of cellulosic material studied.

Cornstalks are also known to be the carriers over winter of the organism which causes wheat scab and where infected stalks remain on the surface of the ground, this disease may be spread far and wide by the wind. Less danger is to be feared when they are plowed under. It is quite possible that complete disposition of crop wastes is desirable in the case of cotton stalks also, which plant pathologists regard as the over-winter carriers of the organism which causes cotton-root rot. Still another danger from the plowing under of matured crop residues is often found on sandy soils or in dry seasons and a farmer who has plowed under strawy manure or other unrotted crop residues often discovers later that the drying effect of these materials on the soil seriously reduces subsequent crop yields. Cornstalks are exceptionally objectionable in this respect. They are not only likely

to take moisture out of the soil to the detriment of plant growth but by their bulk may open up the soil to drying-out processes which may be very serious.

Although he was not the first man to direct attention to the importance of considering the value of fertility removed in products sold from the farm, the late Prof. C. G. Hopkins of the University of Illinois brought this thought home to all farmers who heard him speak or read his contributions to the science of agronomy. In Bulletin 123 of the Illinois Agricultural Experiment Station, he and an associate, J. A. Pettit, estimated the fertility in a ton of corn stover to be—nitrogen, 16 pounds; phosphoric acid, 2 pounds; potash, 17 pounds. Jones and Huston, whose Bulletin 175 from the Indiana Agricultural Experiment Station has been already quoted in discussing corn-stover yields, estimated the amount of fertility removed per acre in the corn stover from shocked corn in their experiments to be—nitrogen, 29 pounds; phosphoric acid, 5.7 pounds; potash, 61.7 pounds. The amount of dry matter per acre of corn stover harvested and cured in the shock in these Indiana experiments was practically 2 tons per acre, which gives these figures as the amount of fertility in corn stover per ton of dry matter—nitrogen, 15 pounds; phosphoric acid, 3 pounds; potash, 31 pounds. This estimate conforms closely to that of Hopkins and Pettit except for potash.

An estimate of the National Fertilizer Association to the author gives the following approximate costs of these three important fertilizer constituents on farms in the central Corn Belt—nitrogen, 12.5 cents per

pound; phosphoric acid, 5.6 cents per pound; potash, 4.75 cents per pound.

Taking these cost figures we get the following estimates of the value of fertility in a ton of corn stover:

Hopkins and Pettit (Illinois)		Jones and Huston (Indiana)	
Nitrogen	$2.00	Nitrogen	$1.875
Phosphoric acid ..	.112	Phosphoric acid ..	.168
Potash	.8075	Potash	1.4725
	$2.9195		$3.5155

The trouble with accepting these estimates without reservation is that, since the investigations were made on which they are based, the important discoveries in soil chemistry and plant pathology referred to have put the subject in an entirely different light from what it was in Hopkins' day. For example, the nitrogen in corn stover, instead of having a value of $2 a ton, is probably worth no more than half of that, on account of the nitrogen needed from a source outside the cornstalks to rot them. It is evident that a great deal more study of this subject is needed before we are sure of our ground.

If all farmers uniformly plowed under their cornstalks or straw and found the practice desirable from the standpoint of practical farm management, there would be no argument on this subject, but the practice of farmers differs widely. Since the opinion of farmers and their practice differs in this respect it is not surprising to find a similar difference of opinion among agronomists at the state agricultural experiment sta-

tions. The author is privileged to quote the opinions of agronomists and soil chemists who have studied this subject carefully. These opinions were given in reply to a letter of inquiry sent to them by Mr. Harvey J. Sconce of the Cornstalk Products Company. Mr. Sconce's letter was as follows:

CORNSTALK PRODUCTS COMPANY, INC.
Danville, Illinois.

March 13, 1928.

In all our work here in harvesting cornstalks for our manufacture of cellulose, the great question that is in the minds of all the farmers is "How much fertilizer value are we selling when we sell a ton of cornstalks?"

I am writing to a great many of the best authorities over the country for an answer to this important question, and am asking your opinion as to what you really value the fertility of a ton of cornstalks, when returned to the soil in the ordinary manner of discing in the stalks when sowing oats, which is the common practice of the middle-west farmer.

You have your figures as to the amount of chemicals in the stalks, but the figures as we have them from Doctor C. G. Hopkins' writings at the University of Illinois gives the Nitrogen 16 lbs., Phosphorus 2 lbs., and Potassium 17 lbs., for a ton of corn stover.

The question really is: How much of these materials is available for the following crops?

What is the market value of these materials when considering the value to the crops?

In view of the fact that these old cornstalks are seriously infected with Scutellum rot, Diplodia, Gibberella, and Fusarium diseases, and that when these infected stalks are turned under in the spring, that they infect the entire soil area in which the new plants are grown, how much then is

the value of the stalks as a fertility medium neutralized by this plant infection that is spread broadcast every season?

As we know the wheat scab and corn root rot is caused by Gibberella saubinetti. What is the fertility value of the stalks in the following crop of spring or winter wheat if the wheat scab is transmitted to the wheat plant because the cornstalks covered with infection were permitted to remain in the field?

With the advance of the corn borer over our country and the governmental demand that the stalks be removed at our own cost, what then is the fertilizer value and our position in the matter?

* * * * (Signed) HARVEY J. SCONCE,
Manager of Raw Production.

A few of the replies to this letter of inquiry were as follows:

W. L. Burlison, Head, Department of Agronomy, University of Illinois, Urbana, Ill.:

This letter is sort of a composite of the best thought which we have on your communication of March 13 regarding the value of cornstalks and some problems connected with the management of cornstalks. Will you take this statement as our best judgment at the present time, but I hope you will bear in mind that we will be gathering information right along on this subject.

Traditionally, cornstalks are considered to have a definite soil fertility value. Many farm leases forbid the tenant burning them and insist that they be turned back into the soil. Unfortunately, however, there is little or no data available which would throw any light on the extent of their value when used in this way. Some base the value of cornstalks from the soil fertility point of view on the amount and commercial value of the nutrient ele-

ments contained in them. Obviously, this is a poor standard of value since the real value can only be measured in terms of the crop increases resulting from the use of them. Field investigations making use of cornstalks for soil improvement purposes usually accompany the incorporation of cornstalks into the soil with other kinds of crop residues, such as straw, second crop of clover or even sweet clover used as a green manure. Obviously, the crop yield increases resulting from such practices cannot be credited to cornstalks alone.

On the Illinois soil experiment fields, a system of farming depending upon the incorporation of crop residues into the soil has been practiced for many years. This system has been practiced without the influence of any other soil treatment. All the cornstalks have been disked or plowed back into the soil. For a number of years the oats and wheat straws were also returned to the land. In order to increase the amount of residues that could be plowed into the soil legumes of various kinds have also been grown. On most fields sweet clover has been seeded for use as a green manure. Only a few of the fields, however, have produced any sweet clover due to the need of the soil for limestone. On many fields red clover has been grown regularly in the crop rotation. It has been the custom to plow down the second growth along with the other residues. Although red clover has been more successful on many fields than sweet clover, it has not been universally successful. On some fields the soil was in too great a need for limestone or other soil treatment materials and only poor growth or no growth at all resulted. There has been but little clover on the light colored soils. Some of the dark colored soils have produced only thin stands of red clover. On some fields soybeans have been grown as a regular crop or as a substitute crop for the clover when it failed. The resulting soybean residues have usually been returned to the soil. For the last half dozen years or so little or no oats and wheat straw have

been returned. Consequently for the last rotation period the chief residues that have been returned and plowed down have been cornstalks, the second growth of clover and green sweet clover on those fields where it would grow without limestone.

* * * *

Those fields which have grown sweet clover have given very much better results for the crop residues. The group of dark colored soils that did not grow sweet clover, but that did grow some red clover when the season was not too adverse, does not show nearly such good results for crop residues. On the light colored soils where no clovers grew and where the crop residues have consisted chiefly of cornstalks, the crop increases have been still less. The average increase in the yield of corn on this group of fields was only 4.0 bushels compared to 5.3 bushels and 12.4 bushels on the other two groups. About the same relationship is shown in the acre value of the increases in the yield of all the grain crops produced.

These results indicate that crop residues possess soil improvement value. Where legumes can be grown, this value may be excellent. Where they do not grow, the other residues available may be used with some profit. These data do not, however, definitely answer the question as to the soil fertility value of cornstalks since other kinds of crop residues have accompanied their use. On those fields where cornstalks have constituted the chief source of crop residues during recent years the crop increases obtained would indicate that some value could be assigned to them, possibly more than enough to pay for the effort expended in plowing them under in preference to burning or removal in other ways.

As far as is known, the only attempt to gather some definite data on the question as to relative value of plowing down cornstalks as compared to burning under Illinois conditions, was some investigations on the University South Farm covering a period from 1914 to 1922. A ro-

tation consisting approximately of corn, oats and sweet clover seed crop was practiced. On certain parts of the field the cornstalks were raked and burned. On other parts of the field the cornstalks were plowed under. Using all possible comparisons for these two methods of handling the cornstalks the crop yields appeared to be better where the stalks were plowed under. The average annual acre yield of corn was 4.4 bushels more and the average annual acre yield of oats 2.3 bushels more where the stalks were plowed under than where they were burned. The odds that these yield increases are significant are high. Out of the twenty-five possible comparisons during this period only four showed negative results.

These results appear to be in harmony with the results reported above from the outlying experiment fields. It would appear, therefore, that the practice of plowing cornstalks under probably has a definite soil fertility value, though the extent of this value is not exceedingly large. More detailed investigations must be made before final conclusions concerning the soil fertility value of cornstalks can be definitely established.

The desirability of eliminating cornstalks from the disease point of view is hard to discuss because for the most part only very little experimental evidence on this subject is available.

That there is a certain value in old cornstalks from the standpoint of soil fertility is, I believe, generally accepted. Therefore, in the past, we have felt that burning cornstalks should not be encouraged because there was not sufficient evidence from the disease angle to show that they did more harm than good *if they are plowed under.* When they are left above ground they will usually disseminate Diplodia and Fusarium spores far and wide, sometimes also Gibberella spores. These cause ear and stalk rots. But when turned under, the effect becomes entirely local, just what the effects are in a crop rotation

in which some other crops follow corn is not well known. It appears now that the diseases you enumerated are primarily responsible for ear and stalk rots and, in case of seed infection, seedling blight which may kill or only stunt the vigor of the plant. True root rot by these organisms in the absence of seed infection is probably not of much importance, at least in a good crop rotation. Most of the real root rot seems to be caused by Pythium which works strictly on the roots, does not come up into the stalks at all, and therefore the stalks cannot be a factor in reinfection.

In the light of what we know at the present time, therefore, we are not greatly concerned over cornstalks as carriers of disease provided they are plowed under.

A. R. Whitson, Chairman, Department of Soils, College of Agriculture, University of Wisconsin, Madison, Wis.:

The question of the fertility lost when a ton of cornstalks is removed from the land is not so simple as it might appear to some. In the first place, there is the question regarding the plant food which would be lost, and, second, as you state, the question of relation of diseases, but there is also a third matter involved which you do not mention, namely the fact that dry matter of this character when plowed under in the soil requires a considerable amount of moisture to decompose it, thus having a drying effect which on sandy soils or during a dry season may more than offset the plant food added. Moreover, this dry matter also furnishes a source of energy for fungi in the soil which use the nitrates in their growth, thus reducing the supply of available nitrates for the growth of the new crop being sown. This effect is known to be every serious in the western wheat-growing regions and it is possible that it may be something of a factor even under our conditions. Considerable research work must

be done before we shall know the exact influence of this factor in this region.

So far as the plant food content itself is concerned, the figures you mention are not quite the same as those given by Henry and Morrison, who state that in corn stover per ton, average analyses show 12 pounds of nitrogen, 7.6 pounds P_2O_5 and 22 pounds K_2O. At present values these would, of course, give a total of nearly $4 per ton. If it were a question of leaving cornstalks from corn which has been husked on the ground standing or of removing them, I think a value of $3 or $4 per ton would not be too high to assign the cornstalks as a fertilizer on any ground high in nitrogen and low in potash, such as muck or peat lands. On soils of this character, in my judgment, they should be left on the field as far as practicable or should be given a value of $3 or $4 per ton if removed. On the other hand, when grown on upland soils lower in water-holding capacity, I think that their benefit as a fertilizer is probably just about offset by the detriment they may cause, though I am quite free to say that we need much more information than we yet have about this matter under our climatic conditions.

G. I. Christie, Director, Purdue University Agricultural Experiment Station, Lafayette, Ind.:

Your letter of March 12 has been carefully considered by Professor Wiancko and the writer.

In a study of plant food removed by crops, we find, in a table prepared and used by the University, it is shown that the average nitrogen, phosphoric acid and potash content in a two-ton crop of cornstalks is valued at $7.88 or $3.94 per ton. These valuations are based on the assumption that the nitrogen in such organic materials is worth half as much as the nitrogen in high-grade inorganic materials like nitrate of soda; that the phosphorus is worth as much as the phosphorus in raw bone, and that

the potash, being water soluble, is equal to that in potash fertilizer. At present somewhat lower prices for commercial nitrogen and potash, we would figure the nitrogen in cornstalks at 10 cents per pound and the phosphoric acid and potash each at 5 cents per pound. At these prices the bare fertilizer value of a ton of cornstalks would now be $3.35 per ton.

We have some experimental evidence on the value of cornstalks and such like crop residues in terms of actual crop increases produced which, after all, is the most practical basis for valuing these materials. We have one such test on the Soils and Crops Experiment Farm on a brown silt loam soil, the results of which would be fairly applicable to the conditions under which you are operating. In this case the rotation is corn, soybeans, wheat, clover. On some plots the cornstalks are left on the ground, the soybean straw is spread on the wheat in winter and the wheat straw is plowed under the clover sod for corn, while on other plots these materials are all removed. As the average of the last four crops of each kind, the increases produced by these residues have averaged 12.6 bushels of corn, 3.8 bushels of soybeans, 0.1 bushels of wheat, and 413 pounds of hay. With corn at 60 cents, soybeans at $1.50, wheat at $1.25 per bushel, and hay at $10.00 per ton, these crop increases are worth $15.45 per acre per rotation of four years. The average amounts of the materials returned have been 3,725 pounds of cornstalks, 2,880 pounds of soybean straw, and 2,360 pounds of wheat straw. I think it is fair to assume that the cornstalks are equal to the average of the other two materials, pound for pound. On this basis we should credit the 3,725 pounds of cornstalks with having produced $6.42 worth of crop increases, which is at the rate of $3.45 per ton. On some of the lighter colored soils which are evidently more in need of organic matter than the soil here at Lafayette, as at Bedford and Worthington, the returns from such crop residues have been consider-

ably higher, averaging $7.17 per ton at Bedford and $4.38 per ton at Worthington. It does not seem to matter much whether the cornstalks are plowed under or left on top. These data would indicate that the theoretical calculated fertilizer value is not too high and that for soil needing organic matter the value of such materials may be considerably higher, as shown by the actual increases produced. On black soils already well supplied with organic matter, we would expect the value to be somewhat lower than on our farm here. We doubt if there is much to be said on the argument that removing cornstalks will eliminate corn diseases. In removing the stalks, no doubt some disease organisms would be removed but the stubble and the roots still remain and would propagate any disease present.

Firman E. Bear, Chief, Department of Soils, Ohio State University, Columbus, Ohio:

I don't believe it is worth while to give very much consideration to the amount of nitrogen, phosphorus and potassium in cornstalks as a means of determining their value for soil improving purposes. If one hauls the cornstalks off the field, naturally he has lost whatever amounts of these materials are contained in them, but if he plows cornstalks under he is quite likely, except as the soil is very full of available nitrogen, to suffer a decrease in yield. Cornstalks are so high in carbohydrate materials that when they are plowed under the bacteria of decomposition require for their own bodies more nitrogen than are contained in the stalks, with the result that they are quite likely to compete with the corn plant for whatever other available nitrogen there may be in the soil.

In the early days when the land was new, no particular difficulty was experienced with plowing under cornstalks in so far as available nitrogen was concerned. Farmers

burned the stalks because that was the cheapest way in which to get rid of them. They lost the nitrogen by this process but did not lose the phosphoric acid and potash. The loss of nitrogen was not particularly important as long as the soil was in its virgin state. Later it was decided that they should be plowed under, but difficulty has been experienced as a result of plowing under.

If sweet clover is sown in the corn and plowed under in its green state with the cornstalks; if liberal amounts of well-rotted manure are applied on top of the stalks before they are plowed under; or if readily available nitrogen fertilizers are applied, no such difficulty is experienced. A great many corn farmers have very little manure. Most of them are not plowing under sweet clover for corn and the amount of nitrogen fertilizer that is being applied is practically nil. Under these circumstances I am very doubtful whether it is advisable to plow under heavy crops of cornstalks. I am not so sure but that the old scheme of burning them up is to be preferred, particularly since this not only gets rid of the excessive amount of carbohydrate material but also destroys any insects or disease organisms which may be harboring in the stalks.

A few years ago we applied a 16-ton application of strawy manure to our tomato crop and reduced the yield more than 200 bushels per acre as a result. The only explanation lies with the fact that this strawy material served as do cornstalks to supply the bacteria of decomposition with so much food that they consumed all of the available nitrogen in the manure and in the soil as well. The tomato plants gave every evidence of suffering from nitrogen starvation.

You will find that farmers, as a rule, are convinced that the yield of corn following corn is much less than it is following clover. One of the important reasons for this lies in the fact that the decaying cornstalks robbed the new corn crop of its supply of nitrogen.

J. G. Lipman, Director, New Jersey Agricultural Experiment Station, New Brunswick, N. J.:

Numerous analyses made at our Station of cornstalks show that an average ton of the latter contains about 16 pounds of nitrogen, 5 pounds of phosphoric acid and 20 pounds of potash. This checks very well with the analyses that you quote from Hopkins. It is unfortunate that in estimating the fertilizer value of vegetable and animal materials we often fail to consider the question of availability as well as of total plant food content. The fertilizer value of cornstalks is a case in point. As you well know, ammonia in fertilizer chemicals is now quite cheap. For instance, the wholesale quotations on sulphate of ammonia and nitrate of soda are both well under $50.00 per ton. These and similar materials furnish readily available nitrogen. In our own experiments we find that, at best, the nitrogen in materials like cornstalks and wheat straw is only 50 per cent as available as the nitrogen in nitrates or salts of ammonia. It is evident, therefore, that if we allow a value of 5c per pound for the nitrogen in cornstalks we should be making this value practically the maximum one. Furthermore, on the basis of availability studies and considering the present cost of available phosphoric acid and potash in chemicals, I should consider the phosphoric acid in cornstalks worth no more than 3c per pound and the potash no more than 2c per pound. We have, therefore, values equivalent to 80c per ton for the nitrogen, 15c per ton for the phosphoric acid and 40c per ton for the potash, or a total of $1.35 per ton of cornstalks. The value of the organic matter cannot be easily measured for it will vary from soil to soil. Altogether, however, we should scarcely be justified in assigning a value greater than $2.00 per ton of dried cornstalks.

It is evident that no dogmatic rule can be laid down and no definite standard of fertility value can be estab-

lished for cornstalks on the basis of information now available. The most important fact to be considered by the farmer who sells his cornstalks is to make sure that by so doing he is not depleting the fertility resources in his soil, which may be compared to his bank account, as the author pointed out in the introduction to this book. It is very easy to exaggerate a minor point while one overlooks a much more important one. The statement was made in the introduction that a good legume crop cut for hay or pastured and then plowed under is worth half a dozen crops of cornstalks. As a matter of fact, that statement is under the mark. Farmers in Illinois and elsewhere who are turning to sweet clover with such enthusiasm have found in that formerly despised legume not only highly valuable pasture, but a fertility resource so great that it completely overshadows anything in the way of fertility which may be credited to cornstalks. It is clear that much research and considerable practical experience will be needed before an intelligent answer can be given to the question of the value of the cornstalks on the farm.

It is obviously ridiculous to argue about the fertility value of cornstalks with a man who rakes them up and burns them every spring, or for such a man to contend that they are worth $3 or $5 or some other figure a ton when he would burn them up anyway. Likewise are both sides to the debate off the track when the corn borer is right around the corner and the old stalks must be disposed of before the next crop is planted.

The Coming of the Corn Borer:

The best authorities believe that the corn borer is destined to become a permanent parasite in the Corn Belt, in which case it will be necessary for farmers to dispose of all cornstalks before the next planting reason if they are to continue to grow corn. At the rate of progress which has prevailed since the corn borer entered the Corn Belt the spread of the insect westward has been 25 miles per year. Nothing has occurred to indicate that this westward progress has been checked and it may therefore be expected that at the past rate of progress the corn borer will be at the Mississippi River in six or seven years and it may probably be expected to appear in Iowa in 1934 or 1935.

It is not necessary in this place to elaborate on effective methods of corn-borer control. The farmer who puts his corn in the silo effectually disposes of every larva in the stalks and ears. Not only are large numbers destroyed in the cutting of the fodder but the temperature which develops in the silo destroys all survivors of the cutting process. The farmer is then only concerned with the danger from the larvæ which remain in the stubble and the roots. These he can dispose of by breaking up the stubble and thoroughly plowing it under. Shredding the corn stover will destroy 98 per cent of larvæ present, which will make negligible the possible danger by the offspring of the survivors during the following season. The greatest danger from infested corn will therefore be found in

the cornstalks which stand in the fields through the winter.

The manufacture of cornstalk products seems to fit in with official recommendations for corn-borer control. The corn harvesters which were operating in Vermilion County last fall were cutting the corn within two inches of the surface of the ground and made a clean recovery. A considerable number of ears were snapped off the stalks by the harvesters because so much of the corn was down, but this did not give the owner of the crop any concern when he had hogs available to turn into the field and glean the ears. Where corn so harvested was put through the husker-shredder a thorough job of shredding was done. Supposing Vermilion County to have been in an area infested with corn borers, both the cutting of the corn and the disposition of the stover were in line with good corn-borer control. The possibility of a few moths emerging during the following spring from the stacks of baled corn stover around the factory could easily be controlled if occasion arose.

The utilization of cornstalks for industrial purposes would therefore appear to offer farmers an opportunity to salvage something from their battle with this pest. No group of fair-minded men would take advantage of a situation such as the presence of the borer to profit from the misfortune of the farmers who suffer from its visitation. Neither is it to be expected that the Corn Belt will stop growing corn. Therefore, we may assume that if and when manufacturing enterprises are used as a means of meeting the corn-borer threat, a

fair basis of handling this matter will be worked out between farmers and industrial concerns so that the farmer will be satisfactorily compensated for the corn borer clean-up and the company manufacturing corn-stalk products will be able to get its raw material at reasonable prices.

The costs of the corn-borer clean-up in Ohio and Michigan in the Spring of 1927 ran between $1.50 and $2.00 per acre. The author is indebted to Mr. J. W. Tapp of the Division of Farm Management of the Department of Agriculture for detailed costs of these operations in certain counties in Ohio. These figures appear on the next page.

COST OF CORN-BORER CLEAN-UP IN OHIO, 1927

County	Ashtabula	Medina	Wayne	Seneca	Lucas	Hancock	Fulton	Paulding
No. farms surveyed	61	67	61	55	57	60	77	44
Average size of farm	107.1	87.8	82.8	150.8	135.1	112.5	105.8	166.4
Acres corn per farm	8.7	9.9	12.8	36.8	30.8	24.4	19.5	61.4
Per cent of corn cut	88.6	93.3	97.3	89.6	35.4	82.8	53.0	1.96
Per cent of farmers having silos	59	26	48.4	22.0	3.6	25	26	0
Per cent of farmers having tractors	14.8	29	20.0	51.0	59.7	31.7	54.0	46.0
Per cent of farmers having corn binders	43	26	33.4	67.3	16.0	66.7	9.0	0.0
Per cent of corn ground plowed for next crop	100.0	97.5	89.4	78.8	64.8	80.0	91.3	10.0
Per cent of corn ground plowed because of borer	8.6	7.6	9.8	44.1	14.7	49.3	57.8	.7
Per cent of corn acreage hand picked	100.0	82.6	76.1	64.7	82.7	33.4	69.0	23.2
Normal man labor per A.	9.0	9.68	7.5	3.5	3.0	4.1	3.8	2.1
Extra man labor per A.	7.0	4.39	3.43	3.9	8.25	3.7	5.81	2.35
Normal horse labor per A.	17.5	17.8	17.2	7.5	3.4	9.2	7.3	5.2
Extra horse labor per A.	2.5	2.07	2.49	4.16	5.0	5.81	5.0	3.11
Normal tractor labor per A.	.7	1.3	.5	0.8	1.5	.5	.9	.4
Extra tractor labor per A.	.08	.36	.17	.77	.28	.64	.94	.02
Number of 8-hour days' extra work per farm	7.6	5.4	5.3	18.0	32.0	11.1	9.3	16.1

CHAPTER IX

WASTES FROM SMALL GRAINS

THE utilization of straw in the United States for manufacturing purposes shows a tendency to decline for reasons explained elsewhere in this book. Small grains do not produce as much roughage as corn although the ratio of straw to grain is usually greater than the ratio of corn stover to grain. It also appears that as the supply of available plant food increases the straw-grain ratio tends to increase, although this is not invariably true. In the case of corn we have noted that the ratio of stover to grain appears to decline with the increase in available plant food. This observation runs counter to commonly held opinions among agronomists and the subject seems to warrant further study by them.

Enormous quantities of straw are still wasted and burned on farms and there is considerable interest in a further extension of the use of this product for manufacture. To furnish information for those who may wish details on this phase of the subject, experiment station yields of grain and straw from leading small grains are inserted in the following pages. The manufacturing possibilities of straw are discussed at greater length in Chapters VII and XII.

Wheat

We will now analyze the wheat data from middle west experiment stations where wheat was grown under different methods of soil treatment.

Kentucky:

The data from Kentucky were obtained over a period of 12 years at different points in the State, including the State Agricultural Experiment Station at Lexington.

Kentucky—Wheat	*Average Production per Acre* *Grain*		*Straw*	*Ratio of straw to grain*
	Bus.	Lbs.	Lbs.	Per cent
Manure	6.67	400	705	176
Manure, limestone and phosphate	20.09	1205	2142	178

The average wheat crop on farms in Kentucky for the five years 1921-1925 was 11.6 bushels per acre and for the ten years 1911-1920 it was 12 bushels. Neither is comparable to the experimental yields.

Illinois:

Like the data for corn yields, the figures from the Illinois soil fields are of great value. Wheat records were obtained at 29 different points over the State, all of which also appear in the data for corn and run back to 1909. See Tables X to XII of the Appendix for county details.

The average of all wheat fields in these trials was:

Illinois—Wheat	*Average Production per Acre* *Grain*		*Straw*	*Ratio of straw to grain*
	Bus.	Lbs.	Lbs.	Per cent
No soil treatment....	18.36	1102	1738	158
Manure	21.77	1308	2111	162
Manure and limestone	27.27	1636	2781	170

Without soil treatment, wheat on two soil fields has averaged well over 1½ tons of straw per acre, while

with manure and limestone, 9 of the 29 fields produced more than that amount of straw.

The annual wheat yield on Illinois farms averaged 16.7 bushels per acre for the five years from 1921 to 1925 and 16.3 bushels per acre during the ten years 1911-1920. The wheat in the Illinois soil fields without soil treatment averaged fairly close to these figures which would seem to indicate an average yield of 1500 to 1750 pounds of wheat straw per acre on Illinois farms.

Missouri:

The data for wheat grown on the Missouri experimental fields at Columbia from 1889 to 1918 are as follows:

Missouri—Wheat	*Average Production per Acre* *Grain* Bus.	Lbs.	*Straw* Lbs.	*Ratio of straw to grain* Per cent
Grown continuously without manure or fertilizer......	13.15	789	1643	208
Grown continuously with manure or fertilizer......	18.90	1138	2597	228
Grown in rotation without manure or fertilizer......	18.84	1130	2355	208
Grown in rotation with manure or fertilizer......	25.60	1536	3414	222

The average yield of wheat on Missouri farms was 12.6 bushels in the five years 1921-1925 and 14.2 bushels from 1911-1920—not far from the average of the experimental fields where wheat was grown continuously without manure or fertilizer. The yield of straw in that case was 1643 pounds per acre, which would appear to be close to the State average on farms.

Kansas:

The experiments in Kansas cover 16 years of continuous growth on the same land compared with 16 years in rotation.

Kansas—Wheat	*Average Production per Acre* *Grain* Bus.	Lbs.	*Straw* Lbs.	*Ratio of straw to grain* Per cent
Grown continuously on same land	14.92	895	1895	212
Grown in rotation....	16.29	977	1788	183

The average wheat yield on Kansas farms for the five years 1921-1925 was 12.0 bushels per acre and for the ten years 1911-1920 it was 14 bushels. This shows the average yield at the experiment station where wheat was grown continuously on the same land to be about the same as that on farms over the State at large, with an indicated straw yield of 1895 pounds per acre.

Oats

Oats is not such a desirable crop for the production of straw for manufacturing purposes as wheat or barley. The yield per acre is less and the manufacturing yield is usually smaller.

Illinois:

Following the same method used in the discussion of wheat and corn we find these comparative data from Table XVII:

Illinois—Oats	*Average Production per Acre* *Grain* Bus.	Lbs.	*Straw* Lbs.	*Ratio of straw to Grain* Per cent
No soil treatment.......	40.76	1304	1347	103
Manure	47.18	1510	1586	105
Manure and limestone..	50.58	1619	1781	110

The average oat crop in Illinois for the five years 1921-1925 was 32.3 bushels per acre; for the ten years 1911-1920 it was 37.4 bushels per acre. As both of these yields are less than the yields on the experimental Illinois soil fields, the average yields of oat straw in the State probably does not exceed 1200 pounds per acre. Comparatively few cases are noted in the county details (see Tables XIV to XVI of the Appendix) where oat straw yields run over 1 ton per acre without soil treatment; 6 out of 24 counties where oats received manure and lime ran 1 ton or more of straw per acre.

Missouri:

The data for the various systems in the Missouri soil experiments are shown below:

Missouri—Oats	*Average Production per Acre* *Grain* Bus.	*Grain* Lbs.	*Straw* Lbs.	*Ratio of straw to grain* Per cent
Grown continuously without manure or fertilizer	17.57	562	1031	183
Grown continuously with manure or fertilizer...	28.38	908	2002	220
Grown in rotation without manure or fertilizer....	27.57	882	1654	188
Grown in rotation with manure or fertilizer....	30.46	975	2024	208

The average yield of oats on Missouri farms was 22.4 bushels per acre during the 5 years 1921-1925 and 26.8 bushels during the 10 years 1911-1920. These yields are fairly close to the second and third classes in the Missouri experiments and seem to indicate an average farm production of straw of between 1500 pounds and 1 ton per acre.

Barley and Rye

There is comparatively little data available from the experiment stations on the yields of these crops. The straw yield would seem to be about the same as that of oats. The high yield in Wisconsin of over 5000 pounds of rye straw per acre is probably due to high moisture content. The experiment station states that weights are taken at the same time that the grain is harvested.

Rice

Data obtained by the Bureau of Plant Industry at the Rice Experiment Station, Crowley, La., from 1913-1921, indicate the following yields of rice straw and rice hulls for different varieties.

Class and variety	*Yield per Acre* *Grain*	*Straw*	*Hulls in 100 pounds of grain*
	Lbs.	Lbs.	Lbs.
Long-grain varieties:			
Fortuna	2530	2210	21.0
Delitus	1862	1350	22.0
Tokalon	2443	2310	18.2
Evangeline	2027	1191	21.6
Vintula	2086	1149	20.6
Salvo	1774	1790	22.0
Honduras	1834	2363	20.6
Medium grain variety:			
Blue rose	2086	2520	20.6
Short-grain varieties:			
Acadia	2884	2020	17.2
Wataribune	2727	1777	18.0
Shinriki	2500	1734	19.0

Some use is being made of rice hulls in the manufacture of cellulose. Until this disposition was made of rice hulls, they were burned or used to a small extent as a filler for manufacturing feeds. Rice hulls carry a very high percentage of ash and the ashes from the burned hulls pile up around the mills and become a nuisance.

The cellulose pulp manufactured out of rice hulls competes on the market with other pulp of this character. It is said to be used to manufacture sausage casings which are used in making "skinless franks," a manufacturer of this food product stripping the casings off the frankfurters before he sells them to consumers. This pulp is also used in the manufacture of rice flakes for breakfast food. Gum, adhesives, furfural, decolorizing carbon, as well as cellulose pulp can be manufactured from rice hulls.

Artificial Manure:

The farmer does not have to wait for the manufacturer to buy his raw cellulosic material from him in order to put it through a manufacturing process. He can be a manufacturer himself if he finds it practical to use the new methods of converting straw into artificial manure which have recently been developed. This process promises to make matches out of date as the best means of getting rid of our Mid-West straw stacks. As the native fertility and humus of the soils of the Mississippi Valley approach exhaustion, the replacement of these vital necessities for profitable plant production becomes increasingly important.

The process of converting straw stacks into artificial manure is more bacteriological than chemical but requires chemicals in its application. Experiments at the Rothamstead Experiment Station in England led to the development of a process of adding nitrogenous and other chemicals to straw stacks which brought about the rapid decomposition of the straw by alkaline fermentation, and produced manure which gave equally good results as stable manure when applied to crops. The Rothamstead authorities patented the process and the material used, which is called "ADCO," is manufactured and sold under the patent rights. The ADCO process as developed in England requires so much hand labor that its adoption in the United States has been hindered, but the merits of the proposition warrant the adaptation of the process to American farm conditions.

One of the latest discoveries in soil chemistry is the fact that the micro-organisms which decompose cellulose require the addition of nitrogen before they will act. Dr. E. B. Fred of the Wisconsin Agricultural Experiment Station, who has made extensive experiments with ADCO, informs the writer that he found that the decomposition of straw, when it is used, is materially hastened by using some cheap leguminous hay as a "starter," in addition to the chemicals. Low-grade sweet clover hay, laid down with straw in alternate layers as the stack was built, gave very quick action.

The limiting factor in using such processes on American farms appears to be water, after the labor problem has been met. The stack must be kept wet until it is rotted. In some seasons sufficient rain falls to

accomplish this. In most seasons some water will have to be applied artificially. A drain pipe from the barn roof to the straw stack has been suggested as an easy means of accomplishing this. Care would have to be taken in any case to avoid leaching the fertilizing constituents out of the stack.

CHAPTER X

CELLULOSE FROM MINOR CROPS

THE development of the pulp and paper industries, based on the utilization of wood for its cellulose content, has supplanted to a large extent the use of annual crops for this purpose. Cotton, as we have seen, is a crop whose value is principally derived from the cellulose which it produces, the choice fiber going directly into the manufacture of textiles, while the low-grade fiber is drawn upon to obtain raw material for the cellulose industries. As the demand for cellulose increases and new uses are found for it, more and more attention will be paid to other sources of raw material than trees. The interest in cellulose at present makes it desirable to compile reliable information on the productive possibilities in raw cellulosic material of other crops grown in the United States besides corn and the small grains.

Sorghums:

The yield of sorghums in tonnage per acre, both of the saccharine varieties (sorgos) and of the non-saccharine varieties (grain sorghums), is important. On the Great Plains, these plants usually surpass corn in tonnage yields. The Department of Agriculture, coöperating with the State Agricultural Experiment Stations, has accumulated a very large mass of data

on the subject. No attempt will be made to summarize all this material, but the figures from the station at Hays, Kansas, are cited to illustrate what sorghums will yield under good conditions. Tests of some of the important varieties were as follows:

Variety	*Years Grown*	*Height of Plants Inches*	*Average Production per Acre Grain Lbs.*	*Average Production per Acre Stover Lbs.*	*Ratio of Grain to Stover Per cent*
SORGOS					
Black Amber	1915-21	77	1,447	4,978	344
Red Amber	1914-21	78	1,097	6,117	558
Western Orange ...	1914-21	68	1,437	5,248	365
Kansas Orange	1914-21	78	316	7,662	2,425
Sumac	1914-21	75	562	8,704	1,549
GRAIN SORGHUMS					
Dawn Kafir	1914-21	50	1,299	4,386	338
Sunrise Kafir	1914-21	66	960	5,088	430
Blackhull Kafir	1914-21	55	699	4,987	713
Red Kafir	1914-21	55	932	4,586	492
Dwarf Hegari	1914-16				
	1918-21	52	1,424	4,657	327
Yellow Milo	1914-15	76	1,548	5,197	336
	1919-21				
Dwarf Yellow Milo.	1914-21	46	1,236	3,972	321
Early White Milo..	1914-21	59	1,483	3,299	222
Feterita	1914-21	61	1,373	3,529	257
Schrock Sorghum ..	1914-21	50	842	4,746	564
Freed Sorghum	1914-21	68	1,255	3,228	257
Corn—grown as a check	....	61	790	3,960	501

The sorghums are usually grown as feed on the Great Plains, both seed and stover being valuable for that purpose. The sorgos are seen from the above table to be much the heavier producers of tonnage in that region and both classes of sorghums generally yield more heavily than corn.

Sorghums are usually planted in rows forty to forty-four inches apart or sown in drills or broadcasted, the former method being followed when the crop is planted for grain; the latter when it is desired for hay. In years of short rainfall, the row-planted crops are the heaviest producers. When rainfall is abundant, the drilled or broadcasted crop produces more heavily.

The moisture-free yield of a crop of Red Amber sorgo sown in drills at Hays, Kansas, and cut for hay when the seed was ripe was as follows:

Yield per acre of Red Amber Sorgo, cut for hay when seed was ripe, Hays, Kansas. Moisture-free basis.

U. S. Dept. Agr. Bul. 1260.

Dry matter	6,209 lbs.
Ash	600 lbs.
Ether extract	121 lbs.
Protein	555 lbs.
Crude fiber	1,517 lbs.
Nitrogen-free extract	3,416 lbs.

Attention is called to the notation in a later section of the yield of bagasse from sorgos used for syrup production.

Flax and Hemp:

The hand labor required for producing linen from flax has inhibited this use of the flax plant in America. Imports of flax, hemp and ramie and manufactures of them for the past five years have averaged more than $50,000,000 a year in value as follows:

1923	$50,465,000
1924	57,139,000
1925	52,620,000
1926	52,711,000
1927	55,076,000

The largest item in these imports was fabrics, mostly of linen, an industry which is too exacting in its handwork for the American taste.

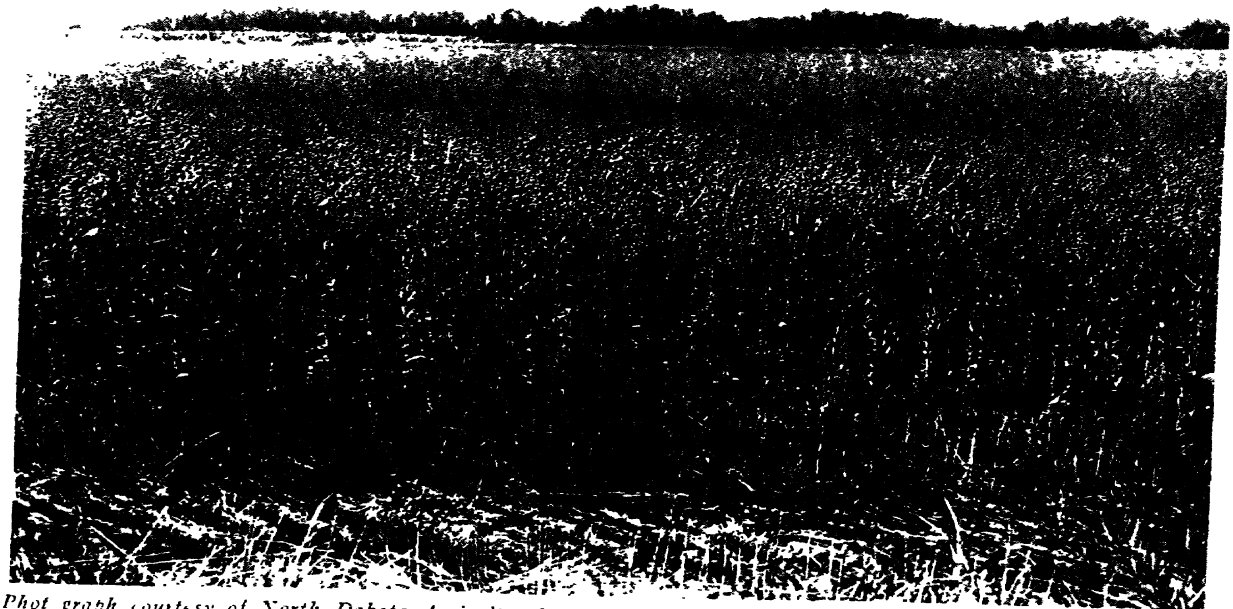
Unmanufactured flax was imported in considerable volume, but the value of these importations is less than 10 per cent of the totals just given. The amounts of flax imported were as follows for the five years:

1923	7,420,000 tons
1924	3,889,000 tons
1925	5,254,000 tons
1926	6,822,000 tons
1927	4,496,000 tons

Flax tow is extensively used as a packing and calking material and straw from seed flax is the source of valuable insulating material. This flax straw seems to have great value for the manufacture of fine paper, but the development of this use depends on the solution of a rather difficult engineering problem.

The Forest Products Laboratory is studying the problem, and Mr. C. C. Heritage, in charge of the Pulp and Paper Section, gives the author the following information:

The bast and shive fibers of flax differ chemically and cannot be used together. The bast fibers are long and when separated from the shives make the finest quality of rag or bond paper.



Photograph courtesy of North Dakota Agricultural College

SEED FLAX IN NORTH DAKOTA

While flax is grown in the United States almost entirely for its seed, the straw is used to some extent in manufacturing.

Photograph courtesy of U. S. Dept. of Agriculture

HEMP

A great producer of cellulosic material, but losing out in America because cellulose is all it does produce.

In the shives the cellulose fibers run all the way from spheres to long fibers. They have poor felting properties, but may make good rayon pulp. The shives comprise the woody core and are 75 to 80 per cent of the stalk; the pith is worthless.

The engineering problem is to separate the bast and shives at one operation of a machine, delivering bast at one spout and shives at another. When this problem is solved the job is done. Yields are indicated as follows:

	2,000	pounds of flax straw	
	700	pounds chaff, sticks, weeds, etc.	
Net	1,300	pounds of clean flax straw of which	
		260	pounds are bast
		1,040	pounds are shives
	1,300 lbs.	1,300 lbs.	

The manufacturer should easily get an 85 per cent yield of paper pulp from the 260 pounds of bast or 220 pounds. A yield of 55 per cent may be expected on the shives or 570 pounds.

"This," says Mr. Heritage, "makes the problem look good enough for further study, but it is a tough one."

Data from the North Dakota Agricultural Experiment Station on yields of flax straw are as follows:

At Fargo, average of 8 years, 2,267 pounds per acre.

At Langdon, average of 3 plots, 1 year, 1,840 pounds per acre.

Not much has been heard of the possibilities of flax straw as a source of cellulose pulp. This product may

become an important source of cellulose although the yield of straw is far lighter than that of corn stover. The quality of cellulose pulp obtained may make flax straw quite valuable for this purpose.

The average acreage for the past five years in the United States of flax grown for seed was 2,875,000 acres annually, almost all of it being grown in Minnesota, the Dakotas and Montana. If we take the Langdon yield above noted as a basis, throw off 300 pounds to be safe, and estimate the average production of flax straw at 1,500 pounds per acre, we get a total yearly production of 2,156,250 tons of straw. At 1,000 pounds per acre, the annual production of straw would be 1,437,500 tons.

As the prime importance of seed flax as a farm crop in America is flaxseed, for the production of linseed oil, we must defer that phase of flax economics for discussion under Chapter XIII.

Hemp:

Hemp is used in similar industrial processes as seed-flax straw and also has great value as raw paper stock, ranking with cotton and linen (flax) in this respect. It will produce great yields of cellulosic material, but it has disappeared almost completely from American farms because its vegetative growth is the main crop and it is not valuable for hay.

According to Mr. L. H. Dewey of the United States Department of Agriculture, the yield of fiber from hemp runs from 400 to 2,500 pounds per acre. The average will be 1,000 pounds, of which three-quarters

are "line fiber" and one-quarter tow. The yield per acre is estimated as follows:

Stalks	*Pounds*
Green, freshly cut	15,000
Dry, as cured in shock........	10,000
Dry, after dew retting........	6,000
Long fiber, rough hemp..........	750
Tow	250
Cost of growing 50 acres, $1,750	
Cost per acre $35	

The last item would indicate a cost per ton of raw material of $7 to $12, which includes baling and marketing.

Hampered though it is by the absence of a seed-producing source of income such as flax enjoys, hemp has value in another direction which deserves consideration. It is a wonderful weed exterminator. The shade produced by the densely growing, heavy-foliaged plants completely discourages any other growth once the hemp plant gets under way. However, the farmer gets about the same results from soybeans, with nitrogen from the air as good measure, which rather spoils that story. There is not much for the American farm in growing hemp, after all.

Soybeans:

The feeding value of straw from most leguminous crops is such that soybeans are not likely to be used as a source of cellulose for some time to come. Yield data on soybeans are given at this point for reference. Records of soybeans grown for eleven years at the

Indiana Agricultural Experiment Station are as follows:

	Average Production per Acre			Ration of Straw to Grain
	Grain		Straw	
	Bus.	Lbs.	Lbs.	Per cent
Soybeans	22.23	1,334	2,561	192

Variety Yields of Soybeans:

Variety tests of soybeans at the Ohio Agricultural Experiment Station are shown in the following table. Varieties are arranged in order of yields of straw.

SOYBEANS IN OHIO [1]

	Average Production per Acre 5-Year Average			Ratio of Straw to Grain; i.e., Lbs. Straw-Lbs. Grain
		Grain	Straw	
Variety	*Bus.*	*Lbs.*	*Lbs.*	*Per cent*
Taha	19.88	1,193	2,786	234
Hamilton	23.49	1,409	2,636	187
Cloud	18.34	1,000	2,510	228
Amherst	23.12	1,387	2,390	172
Sable	14.01	841	2,292	273
Midwest	24.06	1,444	2,278	158
Yosho	19.28	1,157	2,262	196
Ohio 9016	29.22	1,753	2,236	128
Medium Green..	23.87	1,432	2,185	153
Ebony	23.78	1,427	2,166	152
Habaro	23.70	1,422	2,134	150
Mikado	19.85	1,191	2,114	177
Auburn	22.22	1,333	2,110	158
Ohio 9001	24.00	1,440	1,964	136
Ita San	21.17	1,270	1,956	154
Elton	26.51	1,591	1,906	120

[1] After Williams and Park (1917), Ohio Agricultural Experiment Station; from The Soybean, by C. V. Piper and W. S. Morse; New York, N. Y., 1923.

Photograph courtesy of U. S. Dept. of Agriculture

A LUXURIANT CROP OF SOY BEANS

A relatively new crop in America, highly useful to both farmers and manufacturers for forage, feed, soil improvement and oil for paint, varnish, etc.

Photograph courtesy of U. S. Dept. of Agriculture

LOUISIANA RESURRECTS HERSELF

A field of P.O.J. No. 235 sugar cane at Southdown Plantation, Houma, La. As an aftermath of the 1927 flood, nearly all the sugar cane now growing in Louisiana is one of the disease-resistant Java hybrids introduced by the United States Department of Agriculture. Sugar cane bagasse may be used for wall board, paper and other cellulose products whereas it was formerly burned.

These results show that the soybean is not so good a producer of raw cellulosic material as the corn plant, being about on a par with wheat in this respect, but with a somewhat lower straw-grain ratio than wheat.

The Department of Agriculture now reports the acreage and production of soybeans grown for seed, and we find this acreage for 1926 and 1927:

Acreage	598,000
Production	7,128,500 bushels of 60 pounds
Yield per acre	11.9 bushels

Taking an average yield of 11.9 bushels per acre, and estimating a straw-grain ratio of 175 for soybeans, we get an average annual production in round numbers of 375,000 tons of straw as the by-product of soybean seed growing in the United States.

The soybean is a growing crop with many useful applications,—killing weeds, producing feed in large quantity and valuable oil. It may supplant some corn when the corn borer gets itself thoroughly settled in the Middle West. Its use is wrapped up in its well-known proclivities as a producer of oil, and thus we shall defer further discussion of this crop until we reach Chapter XIII.

Artichokes:

When Samuel de Champlain made Nauset Harbor, Cape Cod, Massachusetts, a port of call in the year of our Lord 1605, he found some roots cultivated by the Indians, "which had the taste of the artichoke." One of Champlain's associates, Lescarbot by name, is

credited with having taken some of these roots back to France and soon they were growing all over Europe. By and by the name that Champlain had unintentionally given this tuber was qualified, and "Jerusalem" was affixed, nobody knows when or why. The plant originated nowhere near Jerusalem and never had any connection with the people who made that city immortal.

The Jerusalem artichoke belongs to the same genus as the common sunflower and is thus one of them, with a sunflower botanical name that the great Linnæus gave it, *Helianthus tuberosus,* L. It was once thought that "Jerusalem" came to it as a corruption of the Italian word "girasole," which now means sunflower. But the English called the plant Jerusalem artichoke before the Italians called the sunflower "girasole." So that pretty story fades out. The English did use the word "girasole" for the fire opal and the castor bean when *Helianthus tuberosus,* L., first came to dwell among them, and perhaps that's how they came to get the babies mixed. What's in a name, anyhow? The French call the plant "topinambour," and their "artichaut de Jerusalem" is our summer squash. Some English people have suggested calling it "sun-root" or even "girasole," but habit sticks and "Jerusalem artichoke" it probably will always be in America and England.

After it was taken to Europe, the Jerusalem artichoke spread so fast that people soon forgot where it came from and it was only within the past fifty years that the botanical authorities finally settled the fact that America was its native home.

It is as native to America as the Indian, the turkey, maize, tobacco and the potato, but, although it has been scattered to the ends of the earth in three hundred years, an undomesticated plant it remains to this day, the ugly duckling of our kitchen gardens, often in the garden, but seldom in the kitchen.

Few Americans have ever taken "chokes" seriously, and the only people who have done anything with them agronomically are the French, and they haven't done much.

We owe most of the statistical information about this neighborly stranger to French authorities. In fact, France is the only country which keeps records of the acreage of chokes grown each year and the yields. They have right around 300,000 acres all the time; the lowest yield in twenty-four years was 6,672 pounds of tubers per acre and the highest 17,060 pounds. Chokes held their own during the War,—a lot more than potatoes did, which lost 16 per cent of their acreage while the Germans were trying to get to Paris.

Jerusalem artichokes are a popular stock feed in France and they have been frequently recommended and occasionally used for livestock in America. The strongest champion they ever had in this country was the late Joseph C. Sibley, who was well known as a member of Congress from Pennsylvania, who retired, became an invalid, lived on his farm and grew artichokes for his Jersey cows. From his sick bed he wrote indefatigably about this neglected plant and its value for cattle. Long letters from him may be found

in the files of animal husbandmen all over the country, and he published many articles on the subject. Sibley claimed to get astounding yields and it seems that he did not exaggerate. Reports from state agricultural experiment stations run all the way from 500 to 4,000 bushels of tubers of 60 pounds each per acre—or from 15 to 120 tons. The latter yield was reported from California, and may be regarded as "perfect" or "unusual," like the climate, as you prefer.

Mr. D. N. Shoemaker, of the United States Bureau of Plant Industry, has written the latest word on the Jerusalem artichoke; the facts in this section largely came from him. He says that a plot of chokes at the Arlington Farm, across the Potomac River from Washington, produced at the rate of fourteen tons per acre on good corn land. He cautiously gives his opinion that chokes "will probably yield as heavily as sugar beets."

And that brings us up to the real reason for the interest in Jerusalem artichokes to-day. They can't compete with corn as a livestock feed, nor with potatoes as human food, but they begin to look like a prospective competitor with sugar beets for sugar, because they can be planted, cultivated and harvested with machinery and the seed does not have to come from overseas.

The sugar in the Jerusalem artichoke is levulose, common in fruits and honey. It is from 1.5 to 1.75 times as sweet as ordinary cane or beet sugar (sucrose) and about the same in food value (calories in 1 pound of sucrose, 1,794; in 1 pound of levulose, 1,703).

The trouble with levulose as a commercial sugar was

that it had never been crystallized until the United States Bureau of Standards got after that problem and solved it. R. J. Jackson, Clara G. Sillsbee and Max J. Profitt of that bureau worked it out and all that is needed now is to apply the methods developed in the laboratory to commercial operations in a sugar factory. Samples of Jerusalem artichokes grown at the Arlington Farm seldom analyzed less than 10 per cent sugar, most of them showed 12 to 16 per cent and a few ran over 21 per cent. Nearly all of this sugar was levulose.

Mr. Frederick Bates, chief of the sugar section of the Bureau of Standards, says: "This initial sugar content is in sharp contrast to that of the original sugar beet which contained but 6 per cent sucrose."

So far as can be learned, the only serious objection to sugar from the Jerusalem artichoke is its high hygroscopicity—it absorbs moisture from the air and becomes lumpy or even tends to liquify. However, a manufacturer who is smart enough to get his big technical problem solved so that he can crystallize artichoke sugar ought to be able to solve that problem, too.

The latest development with artichokes is making chips out of them, which are said to be as appetizing as potato chips and keep well. Any one who has enjoyed eating chokes raw out of the garden while mother was not looking can appreciate what a toothsome bite he could get from an artichoke chip.

If and when we start to domesticate the Jerusalem artichoke and put it on the map as a respected member of the horticultural plant lists, the plant breeders will have a lot of fun with it. The "varieties" already

known have a very wide range of characteristics as we have seen, and there is all the country from New York to Minnesota and south to Georgia and Arkansas to roam over hunting for promising wild types.

Like the sweet potato, the roots of the Jerusalem artichoke do not keep well out of the ground. So that brings pathologists and bacteriologists into the picture to solve another important problem.

A weed? Yes, perhaps. But not so pestiferous as its reputation makes it out to be. Its dense shade makes it a splendid weed eradicator on its own account and it can be exterminated easily itself. If the plants are allowed to grow until haying time and are then cut, that settles it, because the tubers are not formed until the days get short. Where corn, forage grasses and small grains are grown in rotation, "Jerusalem artichoke loses all its terrors as a weed," says Mr. Shoemaker. French farmers grow it in rotation. Why shouldn't we?

The purpose of referring to *Helianthus tuberosus,* L., in this place is to point out a by-product, the tops of the plant above ground, the utilization of which may help materially in establishing the economic position of this plant. No definite figures can be cited as to the yield of artichoke tops that may be expected, simply because the plant has received until recently almost no attention from agronomists in the United States. A French investigator reported that the tops would produce nine to fourteen tons of green weight per acre and a few authorities suggest that the tops may be useful for ensilage. The present writer will dismiss the

artichoke with the suggestion that, failing satisfactory use for the silo, the new school of artichoke proponents might look into the possibilities of the tops as a source of cellulose.

Sugar-Cane and Its Cousins:

Sugar-cane bagasse was used only as fuel until the Celotex Company gave cane growers a market for it. Until the introduction of the mosaic-tolerant canes from Java, known as P.O.J. varieties (from Proefstation Oost Java, which satisfactorily explains the abbreviation) the sugar business of Louisiana was in a dying condition.

The mosaic disease of sugar cane is carried from plant to plant by the corn aphid. Varieties heretofore grown in Louisiana succumb. P.O.J. varieties are not affected although they are attacked by the disease; they are "tolerant." As an aftermath of the flood of 1927 which destroyed the common canes, but during which the P.O.J. stock was saved, practically the entire sugar district of Louisiana is now planted to P.O.J. varieties. No more complete revolution in a corn-producing industry has ever been witnessed.

This transformation in sugar-cane growing in Louisiana is an agricultural romance. The story has been quite often told in newspapers, magazines and farm journals, but is well worth repeating here.

The P.O.J. canes were first brought to the United States by the Federal Bureau of Plant Industry from Argentina, where they have proved to be highly resistant to disease. In Porto Rico the mosaic disease

threatened the ruination of the sugar business, just as it did in Louisiana, but by the use of the hybrid P.O.J. canes and of Uba, the sugar industry of Porto Rico got a new lease on life. Uba cane, belonging to an entirely different species, extremely fibrous but quite low in sugar content, had also been found disease-resistant in Argentina; the Porto Rican growers seized on Uba as "any port in a storm."

In April, 1922, Mr. Elliott Jones, field manager of Southdown Plantation in Louisiana, visited the Department of Agriculture and saw some of the P.O.J. canes growing in the greenhouses. He prevailed upon the Department authorities to let him have a few short pieces and took them back to Southdown with him in a suitcase. From this small start the crop of each succeeding planting was saved for further planting.

During the Mississippi River flood of 1927, the "Sugar Bowl" in Louisiana was completely inundated. As the flood progressed southward, it became evident that, unless drastic steps were taken, Southdown Plantation, which is located along the main line of the Southern Pacific Railway toward the southern end of the Sugar Bowl, would also be flooded. Sugar planters were thoroughly alive to the fact that the old varieties of cane in the State could no longer be profitably raised and that unless the P.O.J. canes were generally planted through the Sugar Bowl, sugar production could not continue in that State as a profitable industry. By the spring of 1927 Southdown Plantation had become the principal nursery in the State for P.O.J. canes.

The matter was the subject of grave consideration

among sugar planters and engineers. It appeared that if the levees below Southdown Plantation were cut, Southdown would not be flooded. Would the owners of plantations below Southdown consent to the cutting of the levees which would mean that their own plantations would be flooded and Southdown saved? They not only would but they did. The plan was a success, and as a result it is said that over 90 per cent of all the sugar-cane now growing in Louisiana is one of the P.O.J. disease-resistant varieties.

This remarkable demonstration has undoubtedly revived the sugar industry and has given encouragement to the planters in Louisiana such as they have never had before. Extremely optimistic reports are made of the prospects of the industry in the light of this new development and some enthusiastic planters even predict that eventually the area of sugar production in Louisiana will be so far widened that a million tons of sugar will be produced a year in that State. P.O.J. canes are not only disease-resistant but they are hardy and frost-resistant and it is thought that it will be possible to extend their planting limits beyond anything heretofore known in Louisiana.

The P.O.J. varieties not only are immune to the attacks of the mosaic and other diseases, but they produce greater tonnage per acre in sugar-cane, in sugar and in bagasse, than do the old disease-susceptible varieties. Because all sugar-cane grown in Louisiana in the future will be of these new varieties, data on production before 1925 is ancient history and not comparable with that since 1925.

Returns to the Bureau of Plant Industry from Southdown Plantation show yields of P.O.J. variety No. 234 averaging 25 tons of sugar-cane per acre in 1927. The University at Baton Rouge reported a yield of 41 tons of P.O.J. variety No. 213, and yields of 43 tons per acre were reported from other points. The officials in charge of sugar investigations in the Bureau of Plant Industry predict an average yield in Louisiana of 25 tons per acre for the entire sugar-producing area of the State when the new canes get into full production.

About 500 pounds of wet bagasse will be produced for each ton of cane taken to the mill, and this bagasse will carry from 45 to 54 per cent water. Sugar-cane bagasse in Hawaii will carry 43 per cent water. Mr. Sidney F. Sherwood, of the Bureau of Plant Industry, is authority for the statement that the average of the world's bagasse is estimated at 47 per cent water.

The P.O.J. canes produce about one-third more fiber than the old varieties, and it is reported that the Celotex Company expects to pay a higher price for bagasse from P.O.J. canes on this account. The price paid by the Celotex Company in the past for bagasse is said to have been equivalent to about 25 cents for each ton of sugar-cane produced.[1] A yield of 10 tons of cane

[1] The Company does not buy bagasse direct as a rule. A common plan is for the company to install an oil burner at the sugar mill, making it possible for the planter to replace bagasse with oil for his furnace. This is quite complicated, but it is said to work out to about 25 cents per ton of cane brought to the mill, making *the wet bagasse cost the company $1 per ton at the sugar mill* before anything has been done with it. The grower thus gets $1 a ton net for wet bagasse, on the basis of these figures.

per acre would thus net the grower about $2.50 per acre for his bagasse at this rate. Payment for bagasse is probably the least item of cost to the company of bagasse delivered at the factory. Special baling machinery was needed, as the ordinary hay baler was entirely too slow to be considered,[2] and baling plants were built at the sugar mills. Freight, storage, depreciation and overhead are probably considerable items in the cost of a ton of bagasse delivered to the mill, but so far as the writer knows, the Celotex Company has never published the cost of its raw material.

Louisiana planters estimate that 3,000,000 tons of sugar-cane will be grown in that State in 1928, which will produce 750,000 tons of wet bagasse, or 375,000 tons of bone-dry material. The Celotex Company is said to have contracts with about 75 per cent of the sugar mills in Louisiana, but is not expected to be able to use more than half of the total amount of bagasse produced in 1928-29.

The P.O.J. canes are all hybrids, many of which were developed at the experiment station in Java, which is maintained for the benefit of the sugar industry in that part of the world. The male parent in these crosses was one of the disease-tolerant or resistant fibrous canes indigenous to the Orient, which often carried a low content of sugar. The mother parent was one of the high sugar-yielding varieties which unfortunately proved to be extremely susceptible to disease when the

[2] The same objection holds in baling cornstalks. There must be more speed in baling than hay-baling presses, as they are now made, can produce.

mosaic began to spread through the cane plantations of the West Indies and our Gulf States. The last word has by no means been spoken in the improvement of sugar production by these methods.

A most interesting expedition started in the Spring of 1928 for New Guinea in search of new wild sugar-canes which may be used in the United States for further hybridization. This expedition is under the auspices of the United States Department of Agriculture and is headed by Dr. E. W. Brandes, who is in charge of sugar plant investigations in that Department. Accompanying him is Dr. Jakob Jeswiet, of the University of Mageringen in Holland, who for fifteen years was in charge of the cane improvement division of the East Java Experiment Station. At Honolulu the expedition was joined by Mr. E. C. Pemberton, an entomologist attached to the experiment station of the Hawaiian Sugar Planters Association. Dr. Brandes and his party took a Fairchild cabin aeroplane with them and they propose to fly over the country which they wish to explore. By using an aeroplane they will be able to cover in a few hours an extent of territory which would require months to traverse on foot. The plane is equipped with pontoons so that it is possible to take advantage of water for landing purposes.

Bearing in mind the statement made previously that all data on sugar-cane before 1925 are now out of date on account of the introduction of the P.O.J. canes, some data are given on the chemical composition of sugar-cane from the Louisiana Experiment Station. The

analyses were made of samples of Louisiana Purple, a variety highly susceptible to disease; they are inserted for reference only.

	Pith *Per cent*	*Bundles* *Per cent*	*Rind* *Per cent*
Whole cane (3 analyses)...	2.39	1.81	5.51
Dry fiber	24.66	18.60	56.74

Proximate analysis on a dry-matter basis gave the following results:

	Pith *Per cent*	*Bundles* *Per cent*	*Rind* *Per cent*
Ash	1.68	3.58	1.64
Fat and wax..............	0.41	0.72	0.98
Protein	1.94	2.00	2.19
Cellulose (method of Cross and Bevan)	49.00	50.00	51.09
Pentosans (furfuroids)	32.04	28.67	26.93
Lignin (by difference).....	14.93	15.03	17.17

Japanese cane yields about the same returns in fiber as sugar-cane bagasse. Sorghum (sorgo or saccharine sorghum) will yield 800 pounds of wet bagasse per ton of cane under good conditions, containing about 50 per cent water, according to Mr. Sidney F. Sherwood, of the United States Bureau of Plant Industry.

Peanuts:

Considerable interest in the manufacturing possibilities of peanut shells has been displayed recently by peanut millers. The Bureau of Chemistry and Soils of the Department of Agriculture estimates that from 30,000 to 50,000 tons of this waste are produced annually; it is known that the Virginia mills account for

15,000 tons of it. The analysis of peanut hulls by that Bureau was as follows:

Moisture	10-11 per cent
Fiber cellulose	55-65 per cent
Ash	3-4 per cent
Protein	5 per cent
Nitrogen-free extract	15-17 per cent

From 5.5 to 6 per cent lignin was found, which seems low when compared with lignin reported from other sources.

CHAPTER XI

CELLULOSE CONTENT OF PLANTS

CELLULOSE is the cheapest thing a plant produces, the plant manufacturing it mainly with solar energy by the process which scientists call photo-synthesis. Trees have their value in great part on account of the cellulose which they contain. They are perennial plants whose volume and weight of cellulose is the result of decades or even centuries of natural accretions. If cellulose can be profitably derived from trees, which require anywhere up to eighty years before they are ready to harvest, why not get the same material from a plant which can be harvested within six months after the seed is sown? Especially if the cellulose is found in a by-product of little value obtained in the production of a money crop of much value?

Cotton fiber, long used for high-grade paper and explosives, was the first material to be used for making rayon. It has come into such great demand not only for rayon but for nitro-cellulose lacquers, leather substitutes, surgical dressings, celluloid and the like that cotton linters, once as much of a nuisance to the cotton oil industry as cornstalks are to the farmer, now have an established place on the market as a standard cotton product.

It has been clearly shown throughout this book that chemistry is the basic science underlying the possible development of the utilization of waste products of the

farm in manufacture. In the light of our present knowledge, the most valuable constituent of these products from the manufacturer's standpoint appears to be the cellulose which they contain. It is quite possible that with the development of chemical and technical knowledge, other substances such as the pentosans, xylose and even lignin may prove to have great value in manufacturing. In order to give the reader a fairly accurate idea of the relative value of farm-crop by-products compared with wood, this chapter is devoted to statistical information showing the chemical composition of these materials.

Chemists indicate the purity of cellulose by its content of "alpha" cellulose. Alpha cellulose is used in manufacturing processes for which a high degree of purity is essential, such as the production of rayon and nitro-cellulose lacquers. Alpha cellulose pulp is also an extremely valuable product in the manufacture of paper on account of the large amount of beating which it will stand.

Wood Analyses:

One of the best reference books on the subject is "The Chemistry of Wood," by Hawley and Wise. Two paragraphs from the work of these authors are quoted below to give the reader a little clearer conception of the subject.

"In general, wood cellulose is a residue remaining after more or less drastic treatment of wood to remove lignin and some of the carbo-hydrates other than cellulose. Such treatment may involve the preparation of chemical pulp by any one of the three well-known processes, or, if the

Photograph courtesy of U. S. Forest Service

VIRGIN WHITE PINE IN PENNSYLVANIA

Little virgin timber remains in the northeastern States. As a result lumber and pulpwood are largely crops harvested from annual growth, and the timber industry is steadily growing in importance and stability.

Photograph courtesy of U. S Forest Service

A WHITE PINE "MOTHER TREE" ON A MAINE PASTURE

See what happens when a few old trees are kept to scatter their seed on adjacent soil.

isolation is analytical, may cause the removal of lignin by alternate treatment of the finely divided wood with chlorine and sodium sulphite. In the United States, at least, the term 'wood cellulose' has generally referred to the residue isolated by a chlorination method.

"The residue when subjected to further purification, such as digestion with cold alkali and careful washing with water and acid, has been termed 'alpha' cellulose. The soluble portion removed from Alpha-cellulose may be separated further into two fractions, the one precipitated by acids and arbitrarily termed Beta-cellulose; the other remaining dissolved after such treatment and termed Gamma-cellulose."

According to Hawley and Wise, the ash, cellulose and lignin content of various woods analyzed at the United States Forest Products Laboratory at Madison, Wisconsin, are shown in the tabulations below.

				In Cellulose		
Species	*Ash*	*Cellulose*	*Lignin*	*Alpha Cellulose*	*Beta Cellulose*	*Gamma Cellulose*
Western Yellow Pine....	0.46	57.41	26.65	62.10	10.56	30.13
Yellow Cedar	0.43	53.86	31.32	62.68	11.06	26.25
Incense Cedar	0.34	41.60	37.68	46.92	11.67	41.06
Redwood	0.21	48.45	34.21	78.81	2.95	18.24
Western White Pine....	0.20	59.71	26.44	64.61	16.32	19.06
Longleaf Pine	0.37	58.48	——	——	——	——
Douglas Fir	0.38	61.47	——	——	——	——
Western Larch	0.23	57.80	——	——	——	——
White Spruce	0.31	61.85	——	——	——	——
Tanbark Oak	0.83	58.03	24.85	56.77	19.92	23.03
Mesquite	0.54	45.48	30.47	76.48	2.35	21.17
Balsa	2.12	54.15	26.50	75.64	0.27	24.08
Hickory	0.69	56.22	23.44	76.32	2.82	20.35
Eucalyptus	0.24	57.62	25.07	68.86	0.70	31.10
Basswood	0.86	61.24	——	——	——	——
Yellow Birch	0.52	61.31	——	——	——	——
Sugar Maple	0.44	60.78	——	——	——	——

The results of these analyses as shown are mean values in percentages of oven dry (105° C.) samples.

Field-Crop Analyses:

The following percentages of cellulose in various fibrous plants are quoted from R. W. Sindall's book, "The Manufacture of Paper":

Fiber	*Cellulose Per cent*
Cotton	91
Flax	82
Hemp	77
Ramie	76
Manila	64
Wood (pine)	57
Bagasse	50
Bamboo	48
Esparto	48 to 42
Straw	48 to 40

Most of the available analyses of farm products have been made from the standpoint of their feeding value. For this reason such analyses do not show accurately the cellulose content of things like straw and cornstalks. The livestock feeder is interested in other constituents which are more valuable to him. He consults his feeding tables, looks for protein and then crude fiber and by means of this information satisfies himself as to the value of any feed which he may be about to use. If the protein content is high, nitrogen-free extract high and crude fiber low, the feed should be good. If crude fiber is high, the feeder is wise to be cautious, no matter how high the analysis may show nitrogen-free extract

to be. The amount of crude fiber present is a rough index of the digestibility of the feed in question, and it is mainly cellulose. The manufacturer, on the other hand, will place greatest importance on the cellulose content. What the manufacturer wants, the feeder cannot use.

The standard reference book and chief source of information on the analyses of common farm feedstuffs is Henry and Morrison's "Feeds and Feeding," which contains summaries of analyses of these products made at American Agricultural Experiment Stations. The yield of cellulose in farm-crop by-products will be approximately indicated from the data in the Henry-Morrison tables for crude fiber. The substances classified as "nitrogen-free extract," abbreviated as "N-free extract," are usually obtained by difference and contain some cellulose. It is believed that if 5 per cent be added to the figures for crude fiber in the following tabulations the result will be fairly close to the actual content of cellulose.

Feeding Stuff DRIED ROUGHAGE	*Water*	*Ash*	*Crude Protein*	*Fiber*	*N-free Extract*	*Fat*	*No. of Analyses*
Corn Leaves	23.4	6.2	7.1	22.1	39.4	1.8	28
Corn Husks	24.7	2.5	2.9	24.9	44.2	0.8	17
Corn Stalks	17.7	5.2	4.8	27.8	43.1	1.4	19
Corn Stover (ear removed, very dry)	9.4	5.8	5.9	30.7	46.6	1.6	183
Corn Stover (medium in water)	19.0	5.5	5.7	27.7	40.9	1.2	97
Corn Stover (high in water)	41.0	3.8	3.9	20.1	30.2	1.0	247
Corn Tops	17.9	5.6	5.6	27.4	42.0	1.5	8
Kafir Stover, dry	16.3	8.3	5.1	27.4	41.2	1.7	3
Kafir Stover (high in water)	27.3	7.3	3.8	23.7	36.6	1.3	4

Feeding Stuff DRIED ROUGHAGE	*Water*	*Ash*	*Crude Protein*	*Fiber*	*N-free Extract*	*Fat*	*No. of Analyse*
Milo Stover (high in water)	35.5	6.7	2.3	20.6	34.1	0.8	1
Barley Straw	14.2	5.7	3.5	36.0	39.1	1.5	97
Buckwheat Straw	9.9	5.5	5.2	43.0	35.1	1.3	3
Oat Straw	11.5	5.4	3.6	36.3	40.8	2.4	41
Rice Straw	7.5	14.5	3.9	33.5	39.2	1.4	13
Rye Straw	7.1	3.2	3.0	38.9	46.6	1.2	7
Wheat Straw	8.4	5.2	3.1	37.4	44.4	1.5	27
Sorghum Bagasse (dried)	11.3	2.9	3.4	30.5	50.5	1.4	2
Sugar-Cane Bagasse[1]	10.2	5.6	3.3	34.6	39.2	7.1	1
Buckwheat Straw	9.9	5.5	5.2	43.0	35.1	1.3	3
Flax Shives (straw?)	7.2	7.0	7.2	42.5	32.9	3.2	11
Bean Straw	10.5	7.2	7.3	30.8	42.9	1.3	5
Pea Straw (field)	9.8	5.3	6.1	33.2	44.0	1.6	20
Crimson Clover Straw	12.3	7.0	7.5	38.8	32.9	1.5	3
Cowpea Straw	8.5	5.4	6.8	44.5	33.6	1.2	1
Soybean Straw	11.9	6.8	5.6	36.8	37.2	1.7	8

[1] For reference only, *see* pages 209, 210.

The only information available so far as the writer knows on the yield of Alpha cellulose from cornstalks and straw are the statements of the Cornstalks Products Company.

The Bureau of Standards analyzed two different samples of cornstalk cellulose pulp furnished by this company and reported an average content of 95.6 per cent Alpha cellulose. The company informs the writer that the pulp from which these samples were taken was made in a small mill.

Extending the Use of Cellulose:

Fiber, of course, includes many things, and "nitrogen-free extract," being obtained by difference and constituting such a large amount of the original weight

of the plant, meets the practical immediate needs of the livestock feeder but leaves a lot of chemistry in the dark.

Many chemists believe that the great agricultural developments in the United States during the next half century will be along the lines of producing cellulose and in finding uses for it. If this proves true, the farmer will benefit because he can produce carbohydrates and especially cellulose more cheaply than any other plant product. Cellulose abounds wherever soil and moisture encourage plant growth. Its very abundance staggers the imagination.

The attention now being given to carbohydrate, and especially to cellulose chemistry, indicates that the chemists working on these subjects should soon catch up with the procession. One of the first difficulties which the student encounters in ordinary chemical analyses is this very factor of uncertainty as to the cellulose content or yield. If the analysis of a plant indicates that it contains a certain amount of cellulose, what will be its yield in cellulose pulp in manufacture? There is need for a method of determining cellulose so that by knowing certain facts the cellulose content of a plant can be determined for practical purposes. At present there is no fundamental basis for comparison. This is not an easy problem as can be seen by only a cursory examination of the literature on cellulose chemistry. Easy problems in chemistry as in other branches of knowledge are not left as the last to be taken up.

The romance of cellulose is one of the most fascinating developments of the post-war period, but the

things that have been done are as nothing compared to what may be done when the full manufacturing possibilities of this now little used material are developed.

Nearly 80,000,000 pounds of rayon were manufactured in 1927 in the United States—a tremendous amount—but the cellulose needed for it could have been produced in any good Illinois or Iowa corn county out of cornstalks without the least strain. Even paper, which the average man thinks of as a great national problem so far as the source of its raw material is concerned, is "small stuff" when we balance its requirements against the total output of our forests. If we had to, and if it paid to do so, the cornstalks which now rot or are burned up every year in the Corn Belt could furnish the pulp to make all the paper the country now uses.

The raw material requirements for Celotex, which flashed its way across the horizon to the consternation of the lumber industry, are important to the Louisiana sugar producer, but become insignificant when compared with the possibilities of production of similar material by Indian corn in the Corn Belt. According to the Department of Agriculture, the acreage of corn in Illinois averages 9 million acres each year, of which 89 per cent is harvested for grain. In Iowa the average annual acreage is 11 millions, of which 83 per cent is harvested for grain. So, in Illinois and Iowa together, the cornstalks from 17 million acres are available to the manufacturer. If we take the figure of 2,750 pounds of stover per acre as the probable average annual yield on farms, we have a total production of

corn stover of 23,375,000 tons. If we allow 50 per cent for the weight of the leaves and husks and deduct that, we still have 11,687,000 tons of bare cornstalks. If we allow one-third for moisture content, we have, in round numbers, 8 million tons of bone-dry material, that farmers can't use for feed because animals won't eat it—too much cellulose in it. That is enough raw material in these two states alone for forty-two times the quantity of insulating board that the Celotex Company makes in a year!

What is needed to make cornstalk utilization a source of revenue generally to Corn Belt farmers, is a demand for manufacture that calls for tonnage and lots of it. And that will necessitate chemical research beyond anything that has yet been attempted.

What is cellulose good for that human beings can use, except to make paper and sausage casings, rayon and celluloid, lacquers, explosives and so on? The chemist is responsible for all this agitation and he must answer that question.

A Boston contractor is said to be using a cellulose compound for flooring, and he claims that he has made a number of installations in schools and factories in the vicinity of Boston with good results. This suggests still wider applications, because it is only a step from flooring to other structural uses.

It would seem worth while to investigate the possibilities of putting cornstalks or wood waste through one or more stages of the phenolaldehyde process. Synthetic lumber might be produced which would have all the advantages of the natural product and none of

its disadvantages. It might be possible to go even further and produce by this means something that would be entirely outside the category of lumber uses.

It is a job for the chemist and it is not confined to the utilization of any one product. By-products of the lumber, pulp and paper industry come within the range of this activity as well as the by-products of farming. It is "The New Competition" with a vengeance.

Pure research is needed to develop more accurate and comprehensive knowledge of the characteristics and properties of the cellulose molecule. Given that information, and the man would be foolish who would dare predict the additions to our wealth and comfort which may follow the utilization of our cellulose resources.

CHAPTER XII

THE PROMISE OF CHEMISTRY

THIS is an age of chemistry. The developments which have taken place during the past ten years as a result of the application of chemical research in industry have no parallel in the world's history. Manufacturing processes which have seemed to be well established have passed away almost overnight when some new method was perfected which proved to be more efficient, cheaper, or more profitable than the old one. New enterprises have brought products entirely unknown before into the channels of trade to add to the pleasure and comfort of humanity.

Of the staple farm crops, cotton has been most widely influenced by the genius of the chemist. The utilization now made of cottonseed may be attributed entirely to chemical research and the transformation of cottonseed from a waste product to one of tremendous value to the cotton grower is truly a romantic story.

The use of farm products for other purposes than for food offers to the chemist a rich field for research and there is much evidence that chemical achievements are about to be realized in the industrial field which may have an effect on the production of other staple crops similar to the influence which chemistry has had on cotton growing. Indeed, it is quite probable that the "agricultural chemistry" of the future will be something

very different from what has been conventionally regarded as agricultural chemistry in the past.

The use of farm-crop wastes for manufacturing by chemical processes may result in a development quite as remarkable as that of the chemical processing of coal tar. Let us remember that the plants grown every year on our farms are practically identical in chemical composition with those from which coal was formed during the Carboniferous Era millions of years ago. When the chemist is able to show the technologist, the engineer and the investor that these waste products can be converted by manufacturing processes into products from which a profit can be derived, a market will be opened up for a huge mass of farm products which have never heretofore been utilized or marketed to the best advantage of the farmers who produce them.

The analogy between these common crop wastes and coal deposits is by no means far fetched. The chemists who are studying the utilization of cornstalks, straw and similar material find almost as wide a range of end products as do the chemists who are working with coal tar.

When we are discussing chemistry we can well let our imaginations run riot. The chemist is the most imaginative person on earth. And because he has the skill to make the dreams of to-day the realities of to-morrow, he may well be called the most practical of all scientists.

Distillation Products of Straw:

Some twenty-odd years ago G. H. Harrison was spending the night with a settler on the prairies of

Canada. On account of the scarcity of coal and the absence of wood as fuel this settler was burning straw in a stove supposed to have been designed for the purpose. While the visitor and his host were discussing crops, the weather and the latest political situation, the stove exploded. No account is given of the damage caused, but Harrison escaped with a brand-new idea. He was pretty well informed in chemistry and knew that the cause of the explosion was due to the accumulation of gas which accompanied incomplete combustion of the straw. If this was the case with a stove where the accumulation of gas was not desired, why would it not be possible to apply heat to straw in a retort for the definite purpose of generating gas from the raw material? Why couldn't this be made an industrial development which would solve the fuel problem of the Great Plains? Harrison discussed his new idea with every one who would listen and eventually interested the University of Saskatchewan in Canada, the authorities of which institution gave him a fellowship to study his idea and develop a working process from it. In 1921 the interest of the United States Department of Agriculture was obtained and the Bureau of Chemistry of that Department went into the subject in detail, publishing their results as Bulletin 1203. The equipment used by the Agricultural Department consisted of a cylindrical steel retort 3ft. by 8 ft. with a volumetric capacity of 50 cubic feet, a steel scrubber and condenser combined, and a steel water-seal gasometer.

About 50 pounds of loose, sun-dried straw was placed in the retort and straw was the usual fuel applied in the

fire box. Satisfactory gas was obtained from wheat and oat straw and from cornstalks and the Bureau of Chemistry stated that other investigators had obtained a satisfactory gas from flax and other cereal straws, from corn cobs, wood waste and other cellulosic material.

The analysis of straw gas by Prof. R. D. McLaurin of the University of Saskatchewan was as follows:

	Per cent
Carbon dioxide (CO_2)	30.0
Carbon monoxide (CO)	26.0
Hydrogen (H_2)	26.0
Methane (CH_4)	15.0
Illuminants (ethylene, etc.) (C_2H_4, etc.)	1.5
Nitrogen (N_2) (by difference)	1.0
Oxygen (O_2)	.5
	100.0

This gas made a satisfactory light and had good heating value. It could also be used for operating internal combustion engines, where little air was admitted into the cylinders and a higher compression was used than in most farm engines.

A ton of sun-dried wheat straw gave approximately:

Purified gas	10,000 cubic feet
Carbon residue	625 pounds
Tar	10 gallons

and a quantity of ammoniacal liquors. The gas has a heating value of 400 B.T.U. per cubic foot.

In comparison with gasoline and kerosene, the following values were found:

Straw gas costs 1 cent per 1,690 B.T.U.
At 25c per gallon, gasoline costs 1 cent per 4,320 B.T.U.
At 18c per gallon, kerosene costs 1 cent per 7,110 B.T.U.

Comparisons with wood and coal, making allowances for normal heat losses from the latter were:

Straw gas costs 1 cent per 1,690 B.T.U.
At $10 a cord, wood costs 1 cent per 12,600 B.T.U.
At $15 a short ton, anthracite coal costs 1 cent per 11,435 B.T.U.
At $14 a short ton, bituminous coal costs 1 cent per 13,600 B.T.U.

These costs indicated that straw gas is an expensive fuel when straw is subjected to destructive distillation for that purpose alone. However, Harrison has kept at his idea and has succeeded in interesting St. Paul, Minn., capital in the project, a small plant having been built near that city for the manufacture of products of straw-distillation which the first investigators regarded as by-products. In other words, the gas is now the by-product and what were first the by-products are now the main product. Under this method of approach, the value of the gas produced depends on the use which can be made of it as fuel in the operation of the plant.

The company with which Mr. Harrison is now connected claims yields from a ton of straw of 12,600 cubic feet of gas, 640 pounds of carbon, 15 to 20 gallons of crude "straw oil" and 400 pounds of pitch. They also claim that "in laboratory tests this 'straw oil' is nearer the phenol oil extracted from coal tar products than any other chemical product."

Roofing cement, auto enamel, metal paint, carbon for

various purposes, including the manufacture of rubber tires, auto top dressing, barn paint, fly spray, stock dips, germicides, boiler-scale remover, and rust eliminator are among the products manufactured.

The original idea of producing gas from straw did not prove practical for home use, on account of the cost of the operation and the danger from explosions in a home-operated gas plant. In the method under which Harrison is now working the gas is used as fuel to run the plant, but that only requires about half the gas produced. The rest is wasted, and could be given away without loss to anybody. It seems that a small factory, watching all its costs carefully and looking for cheap fuel, should be able to nestle up to Harrison's company with advantage to both parties.

Still wider applications might follow the development of straw-gas manufacture. The small-grain areas of the United States and Canada are often regions where fuel of any kind is scarce and expensive. Why is it not possible to develop straw-gas production on a community basis in such sections, using the straw to furnish both the fuel to run the plants and the fuel to be sold? If the chemists develop outlets for the by-products of such an enterprise, then straw-gas production might become profitable as the main end of the business.

If such an enterprise should not prove to be a practical industrial development, there is still the manufacture of fuel briquettes from straw to think about. Several years ago Dr. Arthur D. Little of Boston, while studying the industrial possibilities of Western Canada, paid

some attention to this subject, but apparently did not follow it through to completion. An agricultural engineer at one of the experiment stations in the West, looking for a promising subject for research, ought to give some thought to this briquette idea.

After all, the use of straw as fuel is not a highly refined means of utilization. It is elementary and crude, but it is better than burning the stacks, unless, indeed, burning the stacks is the least expensive means to get them out of the way of the plows and seeders. But Harrison has opened up a marvelous list of new substances by destructive distillation. What new wealth lies hidden in the pitch and "straw oil" obtained from straw by the distillation process? We know that furfural is there (there will be more about furfural later). May straw-gas products prove to be a cheaper source of phenol than those already used?

We have seen in preceding chapters that straw from the cereals is more likely to be efficiently used on the farm than some other kinds of crop wastes. No farmer will feed his livestock on bare cornstalks, or sugar-cane bagasse or cottonstalks if he can get anything else, but he can feed straw advantageously if necessary, and he must have it for bedding. If he can turn a straw stack into a valuable manure heap, he may take an important step forward to complete economic utilization of everything his farm produces.

So the trend is towards farm utilization rather than factory utilization of cereal straw. The spread in the use of "combines" throughout the Wheat Belt carries

farm utilization of straw still further along. A combine cuts and threshes the grain at one operation, scattering the straw behind the machine as it is hauled over the fields by horses or a tractor. When combines are used, there are no straw stacks and the straw is plowed back into the soil.

That need not stop our imaginations at all. The things that can be derived from straw can also be obtained from cornstalks or any similar vegetative material. Some products will probably prove to have more variety of chemical substances than others, or one may have greater yields of this or that chemical than others, but all have the same general characteristics—a perfectly amazing array of things locked up in their composition by the mysterious alchemy of nature, which the chemist, daring to meet nature on her own level, can release.

If we do not care to use straw or cornstalks or cottonstalks, then there are many other things which we can use. We could turn to wood and timber wastes, and the author might go into detail on that subject if he had a few more concrete facts to go on. We could grow rank rapid-growing crops just for the cellulose and other things which might be manufactured from them, but the timber owners are doing that now and they have trouble enough trying to make their business pay to discourage any effort yet to produce cellulosic material as a main farm money crop,—cotton of course excepted. When our unused cellulosic farm-crop wastes, which now come as inevitable by-products in the production of staple crops, have found complete utilization on the

farm or in manufacturing processes, then we may turn to cellulose production direct as a farm money crop. And the timber owner can then breathe easy once more.

What Can be Done with Corn Cobs:

The official corn-crop estimates of the United States Government are based on bushels of shelled corn. For every bushel of shelled corn 14 pounds of cobs have been harvested. An average of 2,676,220,000 bushels of corn have been harvested annually in the United States for grain during the past 4 years. This would indicate a total annual production of 19,000,000 tons of corn cobs. There is no possibility that this total production will be available for manufacturing purposes as long as farm practices remain what they are in the Corn Belt. However, we can make an approximation of the volume of this material which is received at elevators and which therefore may be regarded as available. For the 5 years 1921-1925 the average number of cars of shelled corn received at primary markets and graded by licensed inspectors was 314,000 cars; shipments were 185,000 cars; net therefore was 129,000 cars. With a minimum estimate (probably too low) of 1,600 bushels per car, this represents a total of 206,400,000 bushels of shelled corn. The cobs from which this amount of corn was shelled amounted to 1,444,800 tons, scattered among the elevators throughout the Corn Belt, now used mostly for fuel.

A number of investigators have reported the possibilities of corn cobs for chemical manufacture. La

Forge of the Bureau of Chemistry of the United States Department of Agriculture reported that corn cobs had a practical value for the production of furfural, paper stock, adhesive, organic solvents, wood flour, artificial silk, etc. By a process of distillation with mild chemical treatment La Forge estimated that a plant utilizing 100 tons of corn cobs daily would produce 45 tons of adhesive "A," 30 tons of adhesive "B," 35 tons of cellulose, 3 tons of acetate of lime and 1.5 tons of by-product furfural. In addition, by treating adhesive "A" with dilute mineral acids about 25 per cent of furfural in the total solids may be obtained from adhesive "A." At the same time that La Forge was studying corn cobs, Miner was conducting independent investigations on the production of furfural from oat hulls as consulting chemist for The Quaker Oats Company, and obtained about the same yield of furfural from oat hulls that La Forge had recovered from corn cobs. Under Miner's direction The Quaker Oats Company has developed a market for furfural which is constantly growing, but the manufacture of this product consumes only a small part of the total amount of oat hulls produced daily in The Quaker Oats plants.

O. R. Sweeney confirmed the results of previous investigators and extended the number of possible uses of corn cobs, among other things showing that it is possible to add furfural to gasoline and produce an anti-knock motor fuel.

The results of this research work have not been given practical application with corn cobs ror the reason that the production of corn cobs is seasonal. Corn cobs ap-

pear in the elevators from November to May. Other things which yield as much or more furfural, such as oat hulls and cottonseed hulls (see page 59) are produced as a by-product every day of operation. Until the demand for furfural and other chemical products which may be produced from these farm by-products calls for more raw material than is now the case, corn cobs are not likely to be used. The chemical work which has been done is fundamental, however, and will not be lost.

During the last year a product has come on the market in Chicago which is largely made out of corn cobs and is used for insulating houses already built. It is known as Kalkite and is said to be composed of 19 parts of corn cobs, 12 parts of gypsum, and 2 parts of waste paper and chemicals. Corn cobs are bought at elevators at a cost of $1.00 per ton loaded on the cars. They are ground up to about the fineness of granulated cork. The gypsum is used as a binder and the chemicals make the product vermin-proof and practically fireproof. The company handling this product contracts with the house owner to insulate his house without disturbing the contents or occupants. The materials are mixed with about 10 per cent of water which is sufficient to hydrate the gypsum and cause the product to set quickly after being put into the wall. The mixing with water is done by a gasoline engine outside the house, and the material is carried into the house in a pipe from a blower. Holes are bored in the plate between the studs in the attic and the wall is filled in this manner. The attic floor is filled with the material in a

similar way. This product on an attic floor will weigh about 4.45 pounds per square foot. House owners who have used it have expressed satisfaction with it, claiming that they have reduced their coal bills considerably. A test of Kalkite by the National Bureau of Standards showed the thermal conductivity of this material to be .40 Btu per hour, per square foot, per one inch of thickness, per one degree Fahrenheit difference in temperature.

A manufacturer in Ohio is utilizing corn cobs for the production of various materials—for use in plating, drying and polishing metals, and in the production of adhesives, plastics and so on.

The time-honored resort to the corn cob for cheap pipes is too well known to require comment, but it takes a very small fraction of the annual production of corn cobs.

Furfural:

We have seen how the commercial production of furfural was shown to be possible by two different chemists working independently on different raw materials, one using corn cobs and the other oat hulls. When that happened, the price of furfural dropped from $30 to 25 cents a pound and it is now 10 cents a pound. There is nothing especially revolutionary in that. So little furfural had been used that the people who had been in the habit of doing so—the chemists, by the way—were used to paying very high prices for it and locking their supply up in the safe every night. Now that it is cheap, the chemists have all they need, and everybody

else has much more than he needs. Dr. E. E. Slosson in one of his books puts the situation quite aptly: "Furfural Looking for a Job." It's quite true. From an industrial standpoint, the important thing about what La Forge and Miner did with furfural is not so much that they made a chemical rarity cheap, as that now that it is cheap, chemists are puzzled to know what to do with it. The chemists have more furfural than they need in their research work, industry uses all it can use at present prices and more is not used because prices are as they are at present. Then what is to be done? The manufacturers of furfural cannot afford to sell it at a loss just to get people to use it, but the price will not come down until there is sufficient demand to make much larger production necessary. It's a regular chemical merry-go-round.

The fundamental trouble with furfural, like the fundamental trouble with cellulose, is that no chemist knows yet all that chemists ought to know about furfural. The industrial chemists who are working on it have been so busy developing new uses and opening up markets for this new industrial product that they have not had time to take it apart to see what it is made of and how. That's "pure chemical research" and a lot of pure research must be spent on furfural to determine its peculiar qualities before chemists can make the fullest possible use of it.

Even with the fundamental knowledge of furfural as fragmentary as it is, new uses are constantly being found and the demand for it is slowly increasing. It is

valuable as a paint and varnish remover, it is already being used in the manufacture of bakelite because it is an aldehyde and combines with phenol (carbolic acid) to make synthetic resins. It is being used by undertakers as embalming fluid. Reports come from Japan that the people in that progressive country are buying our furfural in large quantities to make synthetic "sake" by combining "essence of sake" made out of furfural with alcohol made out of molasses from the sugar mills in Formosa. By so doing, the Japanese have their cake and eat it too. They relieve themselves of the necessity of making sake out of rice and thus balance the consumption and production of their rice crop, because, before we began making furfural and the Japanese began buying it, the amount of rice made into this highly alcoholic beverage every year in Japan was just about the amount of rice that Japan had to import annually.

Furfural may some day supplement our gasoline supplies as we shall see in the next chapter. This is one of its most interesting characteristics, and the fact that it is so common in crop and wood wastes makes it potentially one of the great unknowns in the field of utilizing these materials.

Corn cobs and oat hulls yield about 10 per cent of their weight in furfural. This is about half the theoretical or laboratory yield. Cottonseed bran, as we have seen, has a laboratory yield of over 22 per cent, which indicates that it is theoretically equql to oat hulls and corn cobs as a source of furfural.

In the production of furfural adhesives are also obtained which should have a wide market.[1]

Insulating Material and Wallboard:

The manufacture of crop wastes into heat-insulating products and wall board is not likely to stop with the present use of such raw materials as sugar-cane bagasse, licorice-root waste, southern wood waste, spruce wood and flax straw, in spite of the fact that only half of the present supply of bagasse in Louisiana may be used, now that Louisiana sugar growers are out of the mosaic shadow and have promise of a stable growing industry with the new P.O.J. sugar-canes.[2]

The manufacture of insulating board is a really new industry although the lumber people vigorously claim that there is nothing new in the idea of insulating houses and that they knew all the time that it could be done with wood. However, the lumber people didn't get their knowledge into the minds of the public. The Celotex Company did that so thoroughly that it is now almost impossible for a builder to sell a new house in some parts of the country unless the roof at least is thoroughly insulated.

The production of insulating materials by chemical manufacturing methods is just in its infancy. The world's supply of cork is not growing, the methods by which cork is produced are primitive and uneconomic

[1] *See* page 259 for a technical description of the characteristics of furfural.

[2] *See* Chapter X.

and sooner or later some ingenious chemist will hit on a process of manufacturing insulation from some other crop product which will be quite as satisfactory as cork.

It is not surprising to learn that all the refrigerator car companies are experimenting with the various insulating boards offered on the market. The thousands of such cars, more of which are needed every year to keep pace with the growth of the trade in perishables, represent only a small part of the demand for insulating materials. The increase in the number of cold storage warehouses, the multiplying multiplicity of refrigerator boxes, ice cream containers, food cabinets and what not which accompany the effort to keep foods in good condition—all of these things offer a potential market in addition to house insulation, and when we add the demand for household refrigeration as good measure, we need not wonder that the chemist in the insulation business is ablaze with enthusiasm.

A heat-insulating material should hold cold in and keep heat out, or keep heat in and cold out, whichever way you wish to look at it. Still air conducts heat slowly, but a "dead-air space" in a wall may be as good a conductor as solid brick or concrete if the air in the space is in motion. And it will surely start to move the moment there is a change in the temperature on either side of the wall. So the job of the insulating engineer is to use insulating material which has very numerous and very small air spaces, in order to reduce air movement to a minimum; but without forcing all the air out and making his "insulation" dense and heavy. A satis-

factory heat-insulating material must therefore be porous without density and weight, and it must be a poor absorbent of water. If it takes up water readily when it gets wet, it loses most of its insulating value. That's why refrigerators should be kept dry.

None of the "synthetic" insulating boards have yet met all these requirements, but there's a world of interest in the subject, and the testing laboratory in the U. S. Bureau of Standards at Washington, which makes the heat conductivity tests, is many weeks behind in its work because inventors of heat-insulating materials have overwhelmed it with requests for official tests of their pet products.

Several commercial products have appeared which have almost as low an index of heat conductivity as cork, but the moisture test usually proves too much for them. The chemist who can hit on a way to make insulating board out of crop wastes, cornstalks for example, which he can fire-proof and water-proof without taking away its valuable insulating properties, can afford a Rolls-Royce for each member of his family.

The manufacture of these materials out of straw and cornstalks has begun within the past year. A company at St. Joseph, Mo., started making insulating board out of wheat straw in 1927 and the Maizwood Products Corporation expects to begin the manufacture of such products out of cornstalks at Dubuque, Iowa, in the summer of 1928.

Broadening the availability of wallboard beyond its use for heat insulation is attracting much attention. Sound insulation is quite as important to tired nerves

as heat insulation is for bodily comfort, food preservation and reduction in fuel bills.

Wall boards have been made out of wood waste, straw and other things for years. Celotex, insulite, masonite and the rest of that class of materials, have opened up an important new field for materials used in building construction. It does not require a fantastic use of the imagination to foresee the development of synthetic lumber made out of wood waste and crop by-products. This may come as the use of wood is more and more restricted to purposes for which it is especially in demand. Of course, a great deal of progress must be made in the chemical treatment of these raw materials before satisfactory lumber substitutes can be made from them. They must be water-proofed and made resistant to attacks of vermin and fire and they must have structural strength.

When the technical problems in this field are solved and manufacturing on a large scale is under way, this outlet for farm wastes should call for large amounts of raw material—in one word, tonnage. A manufacturing demand which needs large tonnage will obviously open up the largest market to farmers for waste crop by-products. It is stated that 2,000 square feet of wallboard can be made from a ton of cornstalks. Using the Iowa estimate of 10,000,000 moisture-free tons of cornstalks as the annual production in that State available for manufacture, Iowa could therefore produce from her unused cornstalks 20,000,000,000 square feet of wallboard a year.

By-products of Cellulose Production:

The recovery of saleable by-products is predicted by chemists of the Cornstalk Products Company as one of the greatest productive possibilities of the process which that company is using. From what has been done by others, this ought to be an important source of revenue.

It is a standard rule of the wood-pulp industry that 100,000 gallons of water are needed for each ton of pulp produced. By using water more than once, the Cornstalk Products Company's chemists expect not only to reduce the total amount of water required to manufacture cornstalks into cellulose pulp, but to concentrate the content of chemical by-products in the liquors by these repeated usings and thus to make the recovery of by-products easier and cheaper.

Dr. E. R. Darling, plant chemist for the company, says that in the first step of the process the water removes the water-soluble pentosans. These substances can be used as adhesives in place of starch, thus releasing starch for food. They can also be used as raw material in the manufacture of butyl alcohol and acetone. They can be hydrolized into xylose and from that point into formic, lactic and butyric acid, all valuable chemicals used in manufacturing. Mixed with alfalfa these pentosans make a feed which cattle like.

Xylose or "wood sugar" is one of the by-products of chemical manufacture of crop wastes that seems to have a real future before it. Chemists are not saying much about it, but it is admitted that the acids which may be produced from it are among its most promising virtues.

Formic acid from xylose may be combined with cellulose to produce cellulose formate. The Germans are said to be using this substance with great success in producing "flat" artificial silk, which does not have the extremely high luster of ordinary rayon.

Xylose as a sugar has food value but is not sweet. It has properties which make it useful for consumption by people who must be careful of their diet. Therefore it might be possible to use xylose in the manufacture of candy that sufferers from nutritional troubles could eat safely. For example, saccharine is very sweet but has no food value. Combined with xylose its sweetness would add what xylose lacks as a confection, while the food value of xylose would supply the lack of food value in saccharine.

The acid leach which follows washing with water in the manufacture of cellulose from cornstalks removes a portion of the pentosans which bind the fibers together and the alkali treatment following this completes the process and prevents the liquor from becoming gelatinous. Dr. Darling states that he can use this liquor at least three times and thus build up its content of pentosans.

CHAPTER XIII

RUBBER, OILS AND MOTOR FUELS

Rubber from American Farms

THE world produced over 600,000 long tons of rubber in 1926, of which 580,000 tons were plantation rubber. Of the total amount 400,000 tons in round numbers,—nearly two-thirds—were consumed in the United States.

The price of rubber per pound in New York during the last 5 years has been:

	Fine Para	*Ribbed Smoked Sheet*
1923	$.248	$.295
1924	.212	.262
1925	.569	.725
1926	.380	.487
1927	.268	.381

A detailed discussion of the world's rubber supply and the efforts to adjust supply to demand and to control prices is impossible in this place. Like other agricultural products, rubber fluctuates seriously in price. Almost complete dependence on foreign supplies of a product which plays such an important part in the daily life of American people makes the rubber supply a serious national problem, which an international complication may render dangerously acute at any time,

whether America is mixed up in the complication or not.

For more than 20 years capitalists interested in our rubber supply have been working on plans to develop sources of raw material in Central and North America. The experiments with native American plants which yield rubber, especially guayule, are noteworthy. There appears to be no intention on the part of the men who are fostering the production of rubber from the guayule plant (*Parthenium argentatum*) to supplant imported Hevea rubber completely. In fact the company which has been most active in developing guayule for the domestic market also owns concessions of over 22,000 acres in Sumatra where it has planted 4,000 acres of plantation Hevea rubber.

Most of the guayule rubber comes from northern Mexico where a subsidiary of the Intercontinental Rubber Company owns about 1,800,000 acres of land from which a portion of the guayule shrub is obtained. The company has experimented with guayule in Arizona and has planted about 1,800 acres on contract with farmers in California. There are said to be indications that the plant may be grown elsewhere.

The amount of guayule used for rubber is increasing as these imports show:

1924	3,038,000 pounds
1925	8,469,000 pounds
1926	9,643,000 pounds
1927	11,174,000 pounds

Guayule rubber contains about 20 per cent resin, which can be taken out when it pays to do so. The

small amount of resin present when guayule rubber is mixed with Hevea rubber does not seem to be objectionable.

Experiments by Spence and Boone at the United States Bureau of Standards "indicate that properly prepared guayule rubber will compare favorably with plantation Hevea rubber."

These tests were made with guayule rubber on standard pure gum, zinc oxide and gas-black formulas and some tests were made by substituting one-half of plantation rubber in a given formula with guayule rubber. The resin in guayule rubber was extracted with acetone in order to admit of a better comparison with Hevea rubber.

It is pointed out that the shrubs used in these tests were two months or more old before extraction and that better results would have been obtained if the shrub had been promptly treated to inhibit deterioration.

Nevertheless, Spence and Boone conclude that—

"the tensile and elongation properties of the products prepared from the guayule shrub by suitable treatment indicate that, when properly prepared, the rubber from guayule will compare favorably with that from Hevea and can be used to a large extent as a direct equivalent therefor without appreciable diminution of the tensile elongation product. The great improvements in the product from guayule to be derived from the successful development of means to prevent the deterioration of the rubber in the shrub is clearly indicated, and it is by no means to be assumed that the last word has been said in this connection.

The values obtained for permanent set are high by comparison with similar samples of plantation rubber, but here,

again, much work remains to be done before definite conclusions can be reached.

Guayule rubber mixes readily with compounding ingredients, because it appears to have a greater capacity for dispersing them than ordinary rubber. This fact calls for a complete investigation of the best means for the utilization of the product to the best advantage.

Since the foregoing tests were made aging tests have been completed upon some of the vulcanized samples after eight months of storage in a box exposed to the outside temperatures, but protected from the light. . . . These results show the usual dropping off in tensile and elongation properties with aging. They also show the marked improvement in this regard brought about by suitable treatment of the shrub. The drop in tensile and elongation in the case of the treated product compares favorably with the results obtained with first latex crepe under similar conditions."

The plantings of guayule in California will give a thorough test of the possibilities of this shrub under cultivation. In its wild state, about seven years are required to bring it to maturity, but under cultivation only four years are necessary.

The following comments on this project are taken from a recent report of the Intercontinental Rubber Company to its stockholders:

"While guayule can be grown on extremely poor lands, such as it selects in nature, still it readily responds to rich, high-priced soils of proper texture, and the value of the crop under intensive cultivation is such as to warrant its use.

On such lands, a crop is ready for harvesting 4 years after planting, and meanwhile it is only necessary to culti-

vate and to keep the weeds down until the plants are large enough to shade the ground. Special machinery, as developed by us, is used throughout. Even under the present improved methods, the production of plantation rubber takes 15 men for every man that will be employed in producing a corresponding amount of Duro brand guayule. If, as, and when it becomes necessary or desirable to shrink the weight of Duro by extracting its resin, thus making a product that will be fully competitive as to price and quality with plantation rubber, the ratio will still be 12 to 1 in favor of guayule. That 12 plantation coolies can now be employed for the cost of one American farmer or factory operative may be granted, but the production of rubber by machinery manipulated by intelligent, well-paid workers is in line with our national industrial genius. That it will eventually be done successfully and on a very large scale seems more than probable."

Although most effort has been directed toward guayule, many other native plants yield rubber—milkweeds and dandelions among others. Some of the milkweeds have been regarded by botanists as promising sources of rubber.

Rubber production in North America is regarded by most of its proponents as a national defense measure and as protection against extortionate methods sometimes practiced by rubber producers in tropical countries. The indignation in the United States which followed the promulgation of the notorious Stevenson Plan for control of the world's rubber market has given way within recent months to mild jubilation on account of the collapse of this plan which followed the fruition of the plantings by Dutch interests in the Far East. From a dominant position in the world's rubber supply,

the British Empire finds that it now produces only 50 per cent of the world's rubber. This increase has come from Dutch sources and has resulted in a decline in the price of rubber to less than 20 cents a pound. This price is quite a little under the figure which the producers of guayule rubber are being paid in the Southwest.

It may be said, however, that there is nothing to prevent a recombination to dictate terms to the American market for rubber. Therefore, a patriotic effort should be made to encourage the production of rubber from American sources. It is not necessary to produce all or even the major part of the rubber which we need for our own purposes in order to protect ourselves against unfair trade practices. From 10 to 15 per cent of the visible supply of any commodity can be made to have a profound influence on its price. The possibility of a war which would cut off our supply of rubber, no matter how remote that may be at the moment, is always something to be considered and is a strong argument with those who would safeguard the United States rubber supply.

Oil-Bearing Plants

Four plants lead in oil production on American farms. Three of them, cotton, peanuts and flax, are of much commercial importance. Soybeans are winning their way; some olive oil is produced in California; and a sixth, the tung-oil tree, is looming up as a real possibility in Florida and elsewhere in the Gulf States. A host of others,—tomatoes, cantaloupes, watermelons,

cucumbers and sunflowers; in fact, almost any plant which produces seed in large quantities—are potential producers of excellent oil which have never been developed commercially in the United States because they have not yet proved to be profitable for that purpose in this country.

We will pass by cottonseed and peanuts not because they are least important, but because cottonseed oil and peanut oil are most valuable as human food and this book is not discussing food products but is confined to things which are not eaten and cannot readily be made edible. Of course, a great deal of cottonseed oil goes into soap and doubtless some peanut oil also. The soap business is a great catch-all for fats and greases of all sorts. Cottonseed oil is used in soap making when it is cheap and the close association between the manufacture of lard substitutes and soap making gives an outlet for low-grade cottonseed oil, which has a stabilizing influence on the market for cottonseed. Olive oil production is of small importance in America and the oil is almost entirely used for food, so we will let that pass.

The plants which are most widely grown in America for oils to be used in industrial processes are flax and soybeans. We will confine our discussion to these two plants and the tung-oil tree.

Flaxseed:

Linseed oil is the main source of revenue from flax in the United States. It is used for paint, in the manufacture of linoleum and oil cloth, in printer's ink and for other purposes. More flaxseed is imported into the

United States than is grown here, and the Argentine crop, coming on the market six months ahead of the United States crop, usually determines the price, although the United States product is said to be of better quality than that from Argentina, with a better color and better drying properties.

Imports of flaxseed and linseed oil together for five years were as follows: (Oil reduced to bushels on this basis—7½ pounds to the gallon of oil, 2½ gallons of oil to a bushel of seed.)

1922	62,959,000 bushels
1923	38,698,000 "
1924	21,005,000 "
1925	21,046,000 "
1926	27,564,000 "

The production of flaxseed in the United States and Argentina was as follows:

	United States Bushels	*Argentina Bushels*
1909-13 Average..	19,543,000	31,117,000
1921-25 "	17,914,000	52,365,000
1924	31,547,000	45,084,000
1925	22,424,000	75,113,000
1926	19,335,000	69,091,000
1927[1]	26,583,000	79,444,000

[1] Preliminary.

These two countries produce more than half the world's total supply of flaxseed. No use is made of flaxseed oil for food, although it has recently been reported that German chemists have worked out a process which makes it suitable for such use.

Soybeans:

Soybeans will eventually far outstrip flax in importance in the United States. Most farmers believe that flax is hard on the soil, while all farmers who have tried them know the benefits derived from growing soybeans. Like other legumes, the nodules on the roots contain bacteria which have the power of fixing nitrogen from the air; so the residual effects of soybeans are highly important in farming. As a farm crop in the United States, soybeans are already equal to flax in acreage. Soybeans have a much wider range of cultivation than flax and a greater field of usefulness. Being a legume, the soybean produces valuable grazing, good roughage and a highly concentrated protein feed (soybean oil cake) as well as the oil, whereas flax is not a legume, is never grazed or made into hay and produces straw which is inferior for feeding purposes.

This versatility of the soybean makes it difficult to say just what it may be like after the plant improvers have worked on it for several decades. As the reader probably knows, the soybean is a native of Asia and its planting in the United States to any extent does not cover a period of more than twenty years. The oil is the stumbling block. The man who is producing soybeans for the oil market naturally wants all the oil he can get. The livestock man would have none of it, if possible. The oil content of soybean seeds often runs over 20 per cent, which makes them very objectionable for feeding. Even when the oil is present in a much smaller amount it causes trouble. Hogs grazed on soy-

beans produce soft oily pork as readily as when grazed on peanuts and are subject to discrimination on the market for this reason.

It has been urged that a soybean to be desirable for livestock use should not contain over 12 per cent fat. This, of course, is diametrically opposed to the viewpoint of the man who is growing the beans for their oil content, but the objection does not apply at all when the oil is expressed and the cake is used as stock feed. Theoretically that is the most economical use to make of soybeans, but practically the livestock farmer is looking for a crop which he can use satisfactorily as a grazing crop if he wishes to do so.

So the plant producers may find it to their interest to work on the soybean from two opposite directions—one, to produce all the oil possible, and the other, to produce as little oil as possible with an abundance of vegetative growth. Already certain varieties are noted as being especially valuable for hay, while others are particularly prolific seed producers. A sharper delineation between high and low oil content in the seed is a matter of simple selection and needs only a few years' time to work out.

Soybean oil is used industrially in the manufacture of inside white paints which dazzle the eye with their brilliance and retain their whiteness a long time without becoming yellow. It oxidizes more slowly than linseed oil, which is the reason for its long-enduring whiteness, but is a slower drying oil than linseed oil and hence is not so suitable for outside paint. Paint experts regard the American soybean oil as being quite as good as

that from the Orient. Considerable "bean oil" used to go into soap manufacture in this country, but the tariff raised the price of domestic soybean oil and soap makers now pass it up for cheaper raw materials. The advent of the corn borer is directing increased attention to the use of soybeans as a standard crop in the Corn Belt.

The imports of soybean oil during the past five years have been:

1923	20,840 tons
1924	4,563 "
1925	9,747 "
1926	15,356 "
1927	7,458 "

The production of soybeans for seed in the United States is now reported by the Department of Agriculture and was for the past two years:

	Acreage	*Production Bushels*
1926	543,000	6,094,000
1927	653,000	8,163,000

Translated into oil, the seed production of 1927 was less than 4,000 tons, but a great deal of that seed, probably most of it, was grown and used for planting, for which the demand offers much better prices than the oil mills are able to pay. By and by when soybeans have been fitted into their proper place in our farm economy with the use of machine operation and systematic management, it will doubtless be possible to produce soybeans for oil in the United States more cheaply than they can be grown in Manchuria.

Tung-Oil Trees:

The tung-oil tree is the latest oil producer which has been brought to this country from Asia. The Department of Agriculture appears to be responsible for the first importation and the records show that on May 16, 1907, the Department brought its initial tree to the United States. What is supposed to be the oldest tree in America, known as the "mother tree," was planted over twenty years ago and still stands at Tallahassee, Fla., honored and revered by tung-oil enthusiasts, as its forebears had been for generations in China.

The tung-oil tree has been called the national tree of China. It is the source of Chinese wood oil, of which we import 40,000 tons or more every year. Tung-oil trees are deciduous, rapid-growing species of the genus *Aleurites*. They begin producing fruit at three years of age on good soil and are said to reach their maximum growth and production at nine years with an expectation of productive life from ten to twenty years more. In China the method of harvesting the nuts is extremely laborious, but in the United States it is thought that they may be raked up and collected at reasonable expense.

On account of unsettled conditions in China, some concern has been felt for the maintenance of a steady supply of such a necessary industrial product. For this reason systematic efforts are under way to establish the growing of tung-oil trees in Florida and elsewhere in the Gulf States. Chinese wood oil or tung-oil is said to be the most important constituent of paint and var-

nish liquids and the most rapid drying oil used in the industry. Tests of Florida tung-oil show that a better product than imported oil may be expected. A report by Mr. H. A. Gardner, of the Institute of Paint and Varnish Research, Washington, D. C., gives the following data:

FLORIDA TUNG-OIL NUTS (1920)

Total weight of shells and meat, 97 pounds

Percentage of shells	55 per cent
Percentage of meat	45 per cent
Percentage of oil in meat	49 per cent

Analysis of Pressed Oil

Appearance	Almost colorless, faint amber tinge
Odor	Faint, but characteristic tung-oil odor

Specific gravity at 15.5° C	.9417
Acid number	.1
Iodine number (Hübl)	170.1
Saponification number	192.4
Unsaponifiable matter	.23%
Browne heat test (minutes)	9-10

EXAMINATION OF TUNG FRUITS SECURED IN FEBRUARY, 1921

Fruits from Dr. Ronald's Plantation (Tallahassee) 1920 Crop.

Outer husk	50 per cent
Inner shell	20 per cent
Meats	30 per cent
	100

Character of Oil Pressed from Meats

Color: Very pale—almost water white

Specific gravity at 15.5° C	.940
Acid value in alcohol-benzol	0.0
Saponification value	195.2
Iodine value	166.0
Refractive index at 25° C	1.5190
Browne heat test (A. S. T. M.)—minutes	9¼

FRUITS FROM GRADY (BATESVILLE, ALA.)

Outer husk	48 per cent
Inner shell	19 per cent
Meat	32 per cent
	100 (Totals 99—G.M.R.)

Percentages of Oil in Meat (by extraction) 64 per cent

Character of Oil Pressed from Meats

Color: Very pale—almost water white	
Specific gravity at 15.5° C	.941
Acid value in alcohol-benzol	0.0
Saponification value	194.3
Iodine value (half-hour, Wijs)	166.6
Refractive index at 25° C	1.5193
Browne heat test (A. S. T. M.) minutes	9¼

FRUITS FROM S. TARNOK (AUGUSTA, GA.)

Character of Oil Pressed from Meats

Color: Very pale—almost water white	
Specific gravity at 15.5° C	.940
Acid value in alcohol-benzol	0.0
Saponification value	195.0
Iodine value (half-hour, Wijs)	165.6
Refractive index at 25° C	1.5188
Browne heat test (A. S. T. M.)—minutes	9½

"The high gravity, high refractive index, remarkable heat test, low acidity and excellent color are noteworthy. A sample of oil from the 1922 crop at Gainesville has just been examined. It was of 0.0 acidity, almost as pale as bleached linseed oil, and had an A.S.T.M. heat test of 9 minutes and a Worstall test of 4¾ minutes. This represents the highest quality of oil ever examined in the writer's laboratory. It would doubtless bring a premium over imported oil."

Strong claims are made for the producing capability of the tung-oil tree. The American Tung-Oil Cor-

poration estimates that the production of oil may average from 400 pounds per acre when the trees come into production to 1,800 pounds per acre when they are mature, estimating 60 mature trees (9 years old) per acre and an oil yield from mature trees of 30 pounds each. Tung-oil plantations are most numerous in Florida, but trees have been planted in Virginia, South Carolina, Alabama, Mississippi, Texas and Arizona. Most plantings in Florida are small, but the Alachua Tung-Oil Company has 2,000 acres planted with tung-oil trees near Gainesville with a total number of about 225,000 trees. In all about 3,000 acres are planted in Florida with the descendants of this newcomer from the Orient and the number is steadily growing.

Oil is not the sole possible product of the tung-oil tree. There is good reason to believe that the residue after the oil is pressed out of the nuts will be quite valuable for fertilizer, if not for livestock feed. Here is one of those by-products-to-pay-the-overhead that makes business go in the face of competition.

Vegetable Oils As Lubricants:

Little use is made of vegetable oils for lubricating purposes, except in mixtures to obtain the advantage of their high viscosity, which is greater than that of mineral oils. There was a great flurry during the War about the need for castor oil for airplanes and a lively controversy has waged among automobile authorities on the subject of the use of vegetable oils. Both have died down, and mineral oils hold the field except as noted. Heavy machinery, railroad rolling stock and

the like, work best with greases to which some animal fat or vegetable oils have been added, and the anti-chatter "Ford Oils" recommended for the Model T Fords are said to contain 3 to 5 per cent of vegetable oil.

The presence of free fatty acids, and their development in storage and use, is the great objection to the use of vegetable oils for lubricating purposes. This does not occur in mineral oils.

Mineral oils, however, are highly objectionable in the textile industry where oil-smears on fabrics injure their quality. Smears caused by vegetable oils can be washed out with soap and water, but mineral oil smears can only be taken out by solvents at considerable risk and expense, if at all. If stains result, the goods must sell as seconds. These losses run into astonishing figures—said to be as much as $100,000,000 a year. The National Association of Hosiery Manufacturers has a research assistant at the U. S. Bureau of Standards in Washington, studying the possibility of substituting vegetable oils for mineral oils in spinning and weaving machinery.

Motor Fuels from Farm Sources

Alcohol:

Some years ago a company manufacturing industrial alcohol from black-strap molasses sold a motor fuel under the name "Alcogas." It was a satisfactory no-knock fuel, and three cents a gallon more could be obtained for it than for ordinary gasoline. The venture

was discontinued because, even with the increased price obtained for the product, it was not profitable.

Oil and gasoline are too cheap in this country for any form of farm-product source of motor fuel to compete with them at present. This fact is overlooked by those who point to Cuba and Germany and other countries where alcohol is used for motor fuel, as examples of what the United States should do. The Cubans have immense quantities of black-strap molasses and no oil except what they import. The Germans have no oil supplies and are compelled to resort to alcohol to supplement the fuel supplies which they import or manufacture from coal. The Germans would use gasoline as Americans do if they had it to use.

The oil supplies (motor fuels) of the United States depend on the underground reservoirs, on the oil-bearing shales and on coal and lignite from which motor fuel may be manufactured. Until those supplies are depleted far beyond any point now in prospect, there will be little likelihood of the American farmer deriving any benefit from the demand for motor fuel.

Dr. C. F. Kettering, of General Motors Corporation, points out that the American motorist is not interested in miles per gallon of gasoline. What he wants is quick get-away, acceleration, speed, miles per hour, and he will pay 25 cents a gallon for fuel as readily as he will pay 20 cents, or even 15 cents if he can get those properties. And, it might be added that he does not mind the price so long as he can get gas whenever and wherever he needs it. Witness the gas stations at almost every cross roads as proof of that.

The retail price of gasoline confuses the mind of the advocate of alcohol as motor fuel who looks no further. He does not know that the wholesale price is around 10 to 12 cents a gallon and that the refiner pays 2 to 4 cents a gallon for his raw material. If we were to start making alcohol motor fuel out of corn we would have to pay a price of 50 to 75 cents a bushel at the lowest estimate. Only 2½ gallons of alcohol can be obtained from a bushel of corn, which makes the raw material cost at least 20 cents a gallon. In addition, a plant to produce alcohol from corn would be far more expensive to build and operate than an oil refinery. The Bureau of Chemistry and Soils of the Department of Agriculture estimates the operating costs of a plant producing alcohol from corn in the United States at 7 cents per gallon.

According to the Bureau of Chemistry and Soils of the U. S. Department of Agriculture, common farm products yield 95 per cent alcohol approximately as follows in gallons per bushel:

Material	*Weight per bushel Pounds*	*Yield Gallons*
Corn (shelled)	56	2.5
Wheat	60	2.8
Rye	56	2.3
Potatoes	60	.8

It should be said, however, that alcohol manufacturers are watching the development of motor engines with the keenest interest. The tendency toward engines with higher compression is steadily growing and high

compression engines require a fuel that burns more completely than do ordinary gasolines, in other words "no-knock" fuels, of which the relatively new tetra-ethyl lead fuels are examples. The higher the compression, the greater the need for these fuels, and as compression increases, the motor engine gets closer to the point where alcohol as well as tetra-ethyl lead may be added economically to gasoline. This will indirectly help to conserve the nation's oil supplies, but it will not help the corn grower, because this alcohol will be made out of black-strap molasses at a cost of not more than 18½ cents a gallon.

Furfural:

Again furfural comes to our attention. The possibility of lowering the cost of manufacturing furfural from farm wastes should be considered in this connection. It may come into use sooner than alcohol.

Dr. C. A. Browne, of the Bureau of Chemistry and Soils, says:

"Furfural is a colorless liquid of pleasant odor, with a specific gravity of $1.1598 \frac{20^\circ}{4^\circ}$, a boiling point of 161.7°, an energy value of 5,985 calories, and a flash point of from 55° to 57°. The yield of furfural from corn cobs and oat hulls, on factory scale operations, is about 10 per cent of the weight of raw material, which is a recovery of about one-half of the theoretical amount.

"Experiments have been made at the Iowa State College on the production of motor fuel by mixing furfural with mutually soluble organic compounds such as acetone,

ether, alcohol, acetylene, kerosene, and gasoline. Furfural was found to be a good solvent for acetylene and small amounts of the latter were found to lower the flash point so that the mixture could be used successfully as a motor fuel. Alcohol was also found to lower the flash point of furfural.

"Furfural is now being produced commercially from oat hulls which are obtained as a by-product of the oat milling industry. The present commercial price for furfural in tank lots is 15 cents [1] per pound although this price is no doubt susceptible of considerable reduction with the extension of uses and development of large scale production. At present prices the use of furfural as a gasoline substitute is out of the question. The possibilitiy of cheap production in enormous quantities from corn cobs, cornstalks, hulls, straw, and other cellular wastes may, however, make furfural a possible competitor of gasoline as a motor fuel in the distant future."

[1] The price is now 10 cents per pound on contract in carload lots.—G. M. R.

CHAPTER XIV

RUBBING ALADDIN'S LAMP

RICHARD WAGNER sang to the evening star. The pine tree raises its head towards heaven in silent adoration of the midday sun.

Where the sun shines most, there, with sufficient water present, plants have the most months in the year for growth. Solar energy, poured on them in such profusion, explains why southern pines grow so much faster than their cousins, the pines and spruces of the north woods. The southern pine tree never has its feet frozen solid in the ice. When spring comes, it begins growing without having to wait for the ground to thaw out, and it has months longer to grow in before the dormant season comes again. The corn plant, under the stimulus of the sun's hospitable warmth, starting from seed in late April or May, equals the annual growth of the pine tree when the long days of blazing summer sunshine force the marvelous manufacturing operations of its countless cells into high-speed activity.

Small wonder that ancient man, keenly conscious of a manifestation of almighty power which he could not understand, developed the cult of sun-worship in which thousands of devotees knelt in reverence for the mighty force above them. To-day we moderns, more accurate in our knowledge of principles, more skillful in technique, but scarcely less correct in our deductions, may

turn this tremendous supply of energy to our daily needs. A few years' time suffices to cover a barren burned waste with glorious pines, a few months to produce, from leagues upon leagues of fallow soil, luxuriant crops of cotton, sugar-cane or corn.

What greater miracle can be imagined than that which we witness during every growing season from sunrise to sunset? How does a plant manufacture with such accurate precision in utter silence carbohydrates from the carbon, hydrogen and oxygen of the air? The process is photo-synthesis, the sun's rays are the source of energy, these three elements are the raw materials, the plant's cells are the factory where carbohydrates are made. But no man has yet explained the process, nor made a carbohydrate as the plant makes it. The carbohydrates—starches, sugars, pentosans, cellulose and the like—are organic materials and can be used by animals in search of food as sources of bodily tissue and energy.

Over seventy years ago, William Henry Perkin, an eighteen-year-old British boy whose waking hours were filled with dreams of the possibilities of chemistry, was attempting to make synthetic quinine out of coal-tar products when he hit upon the first aniline dye, later called aniline blue or mauve. The developments which have followed Perkin's discovery of the possibilities of this unpromising raw material have made his name immortal in the annals of chemistry.

The progress which Perkin's research ushered in was no more an industrial miracle than the transformation which awaits the work of chemists who will point the

way to the utilization of the waste products which the farms and forests of America produce every year, when chemists study these farm and forest wastes as diligently as they have studied mineral wastes. The chemist has shown how to produce cellulose products, paper, building material and a few chemicals from the organic materials produced from the soil, but he has taken only the first few steps along the way. The door to carbohydrate chemistry is flung wide open; the research chemist has barely passed the threshold.

The humble corn cob is a potential source of hundreds of products which the chemist may derive for the use of humanity whenever humanity needs them enough to make it profitable to manufacture them. It is said that the dyes which can now be made from corn cobs are better dyes than the mauve with which Perkin started.

The pentosans—those carbohydrates which may be recovered from cornstalks and straw simply by water and mild chemical treatment—and xylose, close kin to the pentosans, may be transformed into products of great value by chemical processes, awaiting only the magic of some chemical Aladdin to turn dreams and wishes into profitable reality.

One of the most remarkable advances in industry in recent years which is traceable directly to a chemist's laboratory is the manufacture of synthetic resins or plastics, of which the Baekeland process was the first. The key to the production of Bakelite, which was named for the inventor, was the successful combination of phenol (carbolic acid) and formaldehyde. A peculiarity of the phenolaldehyde process is that it may be

stopped at any desired point, each step yielding a product quite different from succeeding ones. Carried to completion, products of great density, hardness, high-insulating and heat-resisting value are obtained. Why may not wallboard made of farm wastes be treated in this way to produce synthetic lumber? This idea has actually been in the minds of chemists in the plastics industry. Only one thing has held it back, and that is the cost of the necessary chemicals. When it is possible to produce phenol and the aldehydes, say furfural as well as formaldehyde, at half, or a fourth of their present costs, some amazing developments may be expected along this line.

If the claim of men like G. H. Harrison is borne out by chemical research, that the destructive distillation of vegetative material such as straw, cornstalks, wood waste and the like produces an "oil" with characteristics similar to those of phenol, why can not the constructive chemist treat those wastes in such a manner that something like the phenolaldehyde process can be accomplished without breaking down the original raw material completely, with the object of producing an entirely new structural material which has all the advantages of wood and none of its disadvantages?

The bone-dry material in a cord of wood used in the manufacture of chemical woodpulp weighs about 2,500 pounds. The pulp manufacturer uses 2.02 cords of wood to produce 1 ton of sulfite pulp, 2.06 cords of wood to produce 1 ton of soda pulp and 2.13 cords of wood for 1 ton of sulfate pulp. In other words, he gets in finished product less than half the weight of

raw material with which he started. The bulk of this enormous loss is lignin, which nature uses in every plant that grows to add strength to stem and branch, but beyond that her purposes have thus far been carefully concealed. Lignin is as widely distributed in the plant kingdom as cellulose itself, and it stands next to cellulose in its abundance in vegetable matter. What is lignin? No one knows. Its molecular structure is only partially determined; the rest is guessed at. Until the chemist supplies this knowledge, the manufacturer has little recourse with lignin except to keep on pouring it into the nearest stream as "black liquor." Dyes, carbon, wood alcohol and many other things may probably be derived from lignin. It may become a valuable source of tanning material. The man who discovers what lignin is and shows what can be done with it will revolutionize the sulfite pulp industry. Will the pulp and paper industry solve this problem of the waste in lignin, and turn lignin into a source of profit instead of loss? Or will it continue to tolerate the loss and allow paper from some other source, say, perhaps, from cornstalks, to replace some of the paper now made from wood by the sulfite process?

The chemist is not the only Aladdin to rub this Lamp of Progress. The utilization of farm-crop by-products in manufacturing processes has in itself by-products with very great possibilities. The farmer will take the Lamp into his own hands, brighten it up and bring about better farm management. By-products which have formerly been wastes are cheap and inexpensive; therefore they must be handled at a minimum

of expense or their disposal costs will run up to a prohibitive figure. That means cost-accounting, and a cost-accounting system is one of the first steps toward more efficient management. When cornstalks are collected for manufacturing, more cover crops will be used; fields will be in better condition in the spring and spring work less rushed with no cornstalks to dispose of. The fertility and organic matter in the soil will be maintained and increased with commercial fertilizers; more legume crops will be planted. With cornstalks in demand for manufacturing material, the agronomist must give the Lamp a rub and bring new varieties of corn into being, better suited than present varieties to produce maximum crops of both grain and stover; the agronomist will be able to tell the farmer how far he can go in producing stover without cutting down the amount of grain produced. The agricultural engineer will conjure away the evil spirits of drudgery which now make corn harvesting an arduous and expensive operation, because the cost of collecting cornstalks must be kept at a minimum and that can only be done by gathering them with machinery, which means, as we have seen, that the entire corn crop will be harvested with machinery when there is a manufacturing outlet for the stalks.

We are now almost at the end of this book, and we trust that the reader has derived as much pleasure from reading it as the author had in collecting the material and writing it up. In his investigation of this subject, an indelible impression was obtained of the resources

Photograph courtesy of U. S. Dept. of Commerce

VIRGIN LONG-LEAF PINE IN THE SOUTH

The man typifies the passing age of lumbermen who depend on virgin supplies of timber for their raw material. The boy, like the young tree which he is holding, looks forward to the day when annual growth of wood will become the most important feature of timber production.

Photograph courtesy of U. S. Forest Service

NATURALLY REFORESTED LONG-LEAF PINE IN ALABAMA

The first step in reforesting the cut-over lands of the South is to stop burning them. Note the indications of old fires in these woods and the results of protection against fires. The young trees are from 3 to 5 years old.

of the United States which the author wishes to share with his readers; namely, the facts presented throughout this book should be sufficient most thoroughly to devitalize the vital statisticians who are continually holding before the eyes of Americans the fear of exhaustion of our natural resources and food supplies.

Some day our oil supplies will be gone, because they cannot be replaced unless perchance the laying down of oil in underground reservoirs is still in progress. When the oil is gone, we shall still have coal supplies to draw upon. When those are gone, we can manufacture kerosenes and gasoline from the oil-bearing shales, the extent of which can only be guessed at.

We have been talking for thirty years in this country about the depletion of our virgin forests, entirely overlooking the fact that a tree in the forest is part of a crop, which, like any other crop, should be harvested when it is ripe. Of course, we can no more draw indefinitely upon our virgin forests than we can draw without replacement on the virgin fertility of our soils. But what American soils can produce in trees, or grains, or forage, oil or fiber, has never been more than partially demonstrated. The demands of the War gave us a glimpse of these possibilities, but even then the production of the soil was far below its maximum capacity. We may worry, we may threaten, but it is a safe prediction that no one now living will see the time when the people of America will need to be seriously concerned about their timber, paper or fuel supplies, much less about their food supply. The production of our farms can be doubled by the application of

known methods and still the limit would not be reached. Foresters believe that the application of scientific methods of producing trees and the intelligent utilization of the products of the forests will result in far greater productive output than we now have, when timber is grown as a crop and not ruthlessly mined without replacement.

America is in no danger of starvation from shortage of food nor are its industries likely to suffer from shortage of raw materials. The danger that threatens, as every farmer knows, is the production of too much material under the temptation of making quick profits and flooding the market with more supplies than the market is able to consume.

An inevitable result of a more complete utilization of farm wastes as raw materials to be used in industrial processes will be a closer working coöperation between agriculture and industry. This may not be desirable from the standpoint of those men who believe that our farmers should keep constantly before them the methods and ideals of the pioneers. Farming is a conservative business and farmers are naturally as conservative as their business, but no farmer to-day would go back to the methods of the early Nineteenth Century, when grain was cut with a cradle and threshed with a flail. The modern industrial system is not perfect and no one thinks it is, but it has proved by results to be the best system yet devised by human ingenuity to bring the greatest material good to the greatest number of people. The American farmer has every right to share in the material comforts which the modern industrial and eco-

nomic system provides. He cannot share those benefits if half or more of what he produces becomes a waste product as soon as his crop is harvested. A market for industrial purposes for the inedible by-products of crop production offers a means for more complete utilization of all the farm produces, with greater prosperity to farmers.